RAILROAD OPERATING COSTS

Volume Two

BY

SUFFERN & SON

Railroad Operating Costs

Arranged to include the operations *of* 1911

A Continuation of Studies in Operating Costs of the Leading American Railroads

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Volume Two

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WHEN we published some eight months ago the first volume of Railroad Operating Costs, we were not certain whether a treatise of this kind, having to do with highly technical matter, would be of sufficient interest to justify its publication. The interest which it seemed to excite among some of the largest and best managed railway systems; the appreciative comments which it received and the fact that in some instances its suggestions were adopted, led us to believe that the studies embodied in the first volume should be extended and enlarged. This seemed specially desirable as practically the only criticism received was that certain roads had been omitted from our study and review.

Such a criticism is eminently just and under it the authors of this compilation must lie for some time, as it is manifestly impossible to complete in a short time such extensive studies covering so many comparisons of various items of costs and to include in these comparisons even all the larger roads. Nevertheless, the work is progressive and is progressing.

In presenting this, the second volume, the authors feel that they can claim that they have advanced somewhat along the paths marked out. The text is recrystallized from a portion of the original material, strengthened and amplified by a great store of new matter, the result of close study since the first edition was prepared; also the arrangement of matter has been materially changed in several respects.

The highly important classification of Maintenance of Equipment is treated of in four chapters instead of in one, as in the first volume. The three additional chapters on Freight Car Maintenance, Locomotive Maintenance and Passenger Car Maintenance embody the results of very careful research, and it is believed that the information thus presented will be of high value, especially as the charts illustrating Locomotive performance for the four years 1908-1911 (inclusive) cover *thirty-six leading roads,* many of which were not mentioned in the first volume. Five charts reflecting Passenger Car performance on *forty leading roads* are shown in place of two charts of fourteen roads in the first volume.

In the chapter of Maintenance of Way and Structures, a new and important unit of cost determination has been introduced, viz., the "Locomotive Tractive Mile," which is believed to be a far more logical unit than that which has been employed previously.

The eighth chapter on Fuel Costs is entirely new. The text contains much of what is believed to be wholly original information with respect to locomotive performance under a great variety of conditions and according to various types of structure and classifications. It is not known that such records have been produced before and the information therein presented is at once important and progressive. Those who are interested in the conservation of our natural resources will be pleased to observe in what manner and to what degree better locomotive performance will serve to reduce coal consumption, while the facts adduced will be of interest to the builders of locomotives and superheating devices. This chapter is illustrated by eleven charts wholly original in their character and subject matter.

The whole volume is arranged to include the operations of 1911, thus bringing the charts and tabulations to date.

SUFFERN & SON.

NEW YORK, May, 1912.

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Railroad Operating Costs

CHAPTER I.

Every railroad in the United States that handles any interstate traffic is required to file annual reports with the Interstate Commerce Commission, on uniform blanks prepared by its statistician and bound in book form. These annual reports present many figures, of various kinds: figures from the financial accounts; statistics of performance; information in respect of the more important sorts of physical properties; and traffic data, highly condensed; but a great many things are missing which it is necessary for a railroad operator or analyst to know in order to utilize these figures in making accurate comparisons between different railroads—comparisons that will instruct, not mislead him. He requires to have information from other sources; an intimate knowledge of local conditions—information general and special—to enable him to make judicious comparisons, draw trustworthy inferences and reach sound conclusions.

The original reports are available for examination in the offices of the Commission at Washington, but few printed copies are made and only a very few of the most general items are extracted for publication in the Commission's statistical reports. Indeed, the paucity of useful information to be gleaned from any published reports of railroad operations and affairs becomes painfully evident to the investigator seeking to make comparisons that will be valuable to practical railroad operators.

With a few exceptions—as the Union-Southern Pacific System, whose reports are models of real information, unequalled in English-speaking countries—annual reports to stockholders are of little use to any but financial men (and often of doubtful value to these), while the summaries appearing in the various financial manuals are almost devoid of information in respect of operating conditions.

If we turn to the bulky statistical tome issued annually by the Interstate Commerce Commission, we find a thousand closely printed pages filled with tables of almost useless data and summaries, while the information absolutely essential to any clear picture of physical and operating conditions on the several railway properties in the United States is conspicuous by its absence, notwithstanding an immense amount of information of great value is sleeping in these reports made by the roads to the Commission from which this volume is derived.

Comparison of operating costs have lately received such wide-spread attention on the part of railroad men and of the public and the National and State governments as well, that an analysis of some of the facts which may be learned from the detailed annual reports reposing on the Commission's shelves appears to be well worth the making and, perhaps, of some immediate value. The writer presents herewith such a study, based in the main upon the railroads' annual reports to the Interstate Commerce Commission (amplified somewhat by information obtained from the Census Bureau and from various railroad officials) in respect of earnings, operating expenses, physical characteristics and operating conditions of the representative railroads of the country, but without special reference to rates or managements.

Previous to July 1, 1907, there was supposed to be a definite system of compiling railroad accounts and statistics, but, as each railroad interpreted the Commission's classifications of separating expenses, etc., in accordance with its own views, reliable comparisons of railway statistics covering earnings, capitalization, cost of operation, etc., were not to be made.

The Hepburn Act of 1906 gave the Interstate Commerce Commission complete authority and control over railway accounts and the Commission after long and tactful negotiations with the accounting officers of the roads promulgated a revised series of accounting rules and classifications of accounts, and since July 1, 1907, the railroads have been keeping their records and submitting their reports accordingly. While these rules permit far greater variation from a uniform standard than is generally understood, their chief defect, from the standpoint of this paper, arises out of lack of operating details and units—a defect due to the fact that the classifications were prepared by accountants who were less familiar with operating than with financial records.

For instance, among all of the voluminous figures submitted by the various railroads, the Interstate Commerce Commission reports give no place to the statement of the gross tonnage hauled one mile (a very important item)—and in fact there are but few railroads in the United States that compile, much less report, this most valuable statistical item.

Total Capitalization per Mile of Road Operated

1911

N. Y. N. H. & H.	$191,840	P. C. C. & St. L.	$ 89.246
B. & M.	37,510	Mich. Cent.	33,389
N. Y. Central	141,394	Pere Marq	51,687
Erie	201,330	Vandalia	41,618
Penn. R. R.	180,607	Wabash	87,146
Del. & Hud	118,401	C. & A.	121,785
D. L. & W.	32,897	Ill. Cent.	67,030
Leh. Valley	104,228	C. B. & Q.	35,334
C. R. R. of N. J.	120,654	C. & N. W.	46,596
Phil. & Read	90,503	C. R. I. & P.	37,018
Balt. & Ohio	122,795	Frisco	81,141
Nor. & West	102,671	M. K. & T.	78,484
Ches. & Ohio	116,906	Mo. Pac. Sys	66,118
Atl. Coast Line	45,029	D. & R. G.	79,172
Seab. Air Line	64,258	C. G. W.	73,029
Southern Ry	62,443	C. M. & St. P.	61,936
Lou. & Nash	46,595	Grt. Nor.	66,565
Nash. C. & St. L.	20,641	Nor. Pac.	85,376
Penn. Co.	150,349	Union Pac.	149,532
L. S. & M. S.	131,468	Santa Fe Sys.	74,123
P. & L. E.	135,814	Sou. Pac. Sys.	59,064

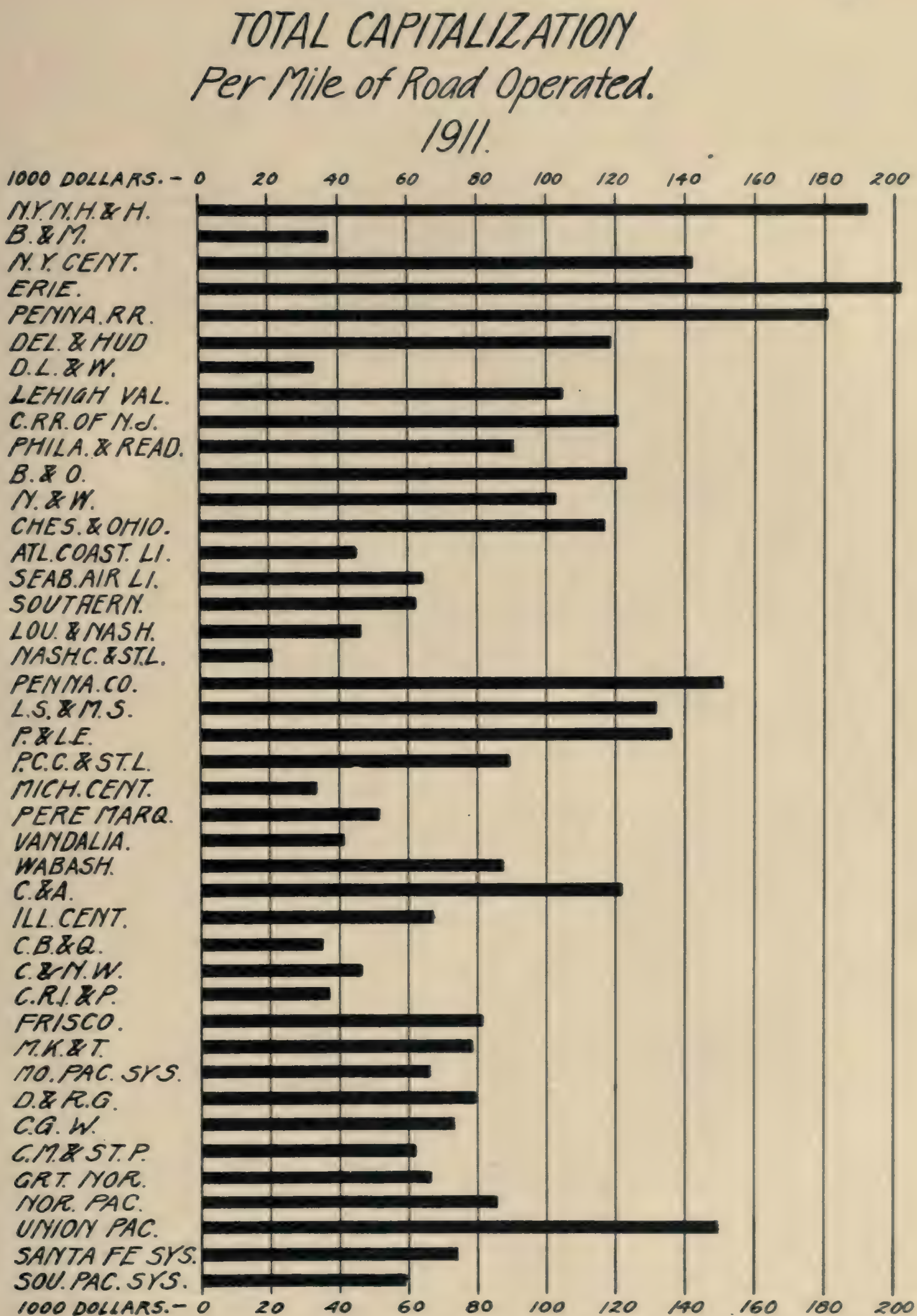

TOTAL CAPITALIZATION
Per Mile of Road Operated.
1911.
1000 DOLLARS.–
0
20
40
60
80
100
120
140
160
180
200
N.Y.N.H.&H.
B.&M.
N.Y.CENT.
ERIE.
PENNA.RR.
DEL.&HUD
D.L.&W.
LEHIGH VAL.
C.RR.OF N.J.
PHILA.&READ.
B.&O.
N.&W.
CHES.&OHIO.
ATL.COAST LI.
SEAB.AIR LI.
SOUTHERN.
LOU.&NASH.
NASH.C.&ST.L.
PENNA.CO.
L.S.&M.S.
P.&L.E.
P.C.C.&ST.L.
MICH.CENT.
PERE MARQ.
VANDALIA.
WABASH.
C.&A.
ILL.CENT.
C.B.&Q.
C.&N.W.
C.R.I.&P.
FRISCO.
M.K.&T.
MO.PAC.SYS.
D.&R.G.
C.G.W.
C.M.&ST.P.
GRT.NOR.
NOR.PAC.
UNION PAC.
SANTA FE SYS.
SOU.PAC.SYS.
1000 DOLLARS.–
0
20
40
60
80
100
120
140
160
180
200

FIG. 1

The capitalization of a railroad, while most important from a financial standpoint, is of but little moment in our present analysis. In order to show, in part, the great difference in capitalization of the various roads, and in part the soundness of a commonly used unit of measurement of capital (the mile of road), a chart is presented, Fig. 1, showing the total stocks and bonds outstanding per mile of road operated, as reported to the Interstate Commerce Commission.

In making analyses of railroad returns from an operating standpoint, the first item to consider is the gross operating revenue or gross earnings. A chart is next presented, Fig. 2, illustrating the gross earnings per mile of road, for the representative roads of the country. The unit used here—the mile of road—is a misleading measure at best in any analysis of operating efficiency.

Of the two items that determine gross earnings, volume and class of traffic, the former is the more important; granted a larger volume of business, even if it be of low rate class, a railroad's earnings will be sufficiently large to make it profitable. The railroad business is particularly subject to the law of increasing return—its expenses do not rise in proportion to increase of business.

Between competing roads in the same territory, or connecting the same terminal centers, the traffic department (the "sales" department) is a most important factor in securing freight—and passengers—which is to say, earnings. But the great factor is industrial development;—particularly in the coal and iron trades, which produce heavy tonnage. This industrial development and agricultural de-

Gross Earnings per Mile of Road Operated

1911

N. Y. N. H. & H.	$30,456	P. C. C. & St. L.	$26,522
B. & M.	19,982	Mich. Cent.	16,491
N. Y. Central	28,051	Pere Marq.	6,858
Erie	24,319	Vandalia	12,603
Penn. R. R.	39,523	Wabash	11,882
Del. & Hud.	24,632	C. & A.	14,330
D. L. & W.	38,649	Ill. Cent.	13,363
Leh. Valley	26,313	C. B. & Q.	9,730
C. R. R. of N. J.	39,116	C. & N. W.	9,706
Phil. & Read.	43,731	C. R. I & P.	8,708
Balt. & Ohio	19,881	Frisco	8,631
Nor. & West.	17,743	M. K. & T.	9,110
Ches. & Ohio	15,866	Mo. Pac. Sys.	7,300
Atl. Coast Line	7,029	D. & R. G.	9,007
Seab. Air Line	7,151	C. G. W.	8,457
Southern Ry.	8,569	C. M. & St. P.	8,650
Lou. & Nash.	11,742	Grt. Nor.	8,452
Nash. C. & St. L.	9,820	Nor. Pac.	10,909
Penn. Co.	36,050	Union Pac.	14,856
L. S. & M. S.	29,138	Santa Fe Sys.	10,728
P. & L. E.	73,053	Sou. Pac. Sys.	12,995

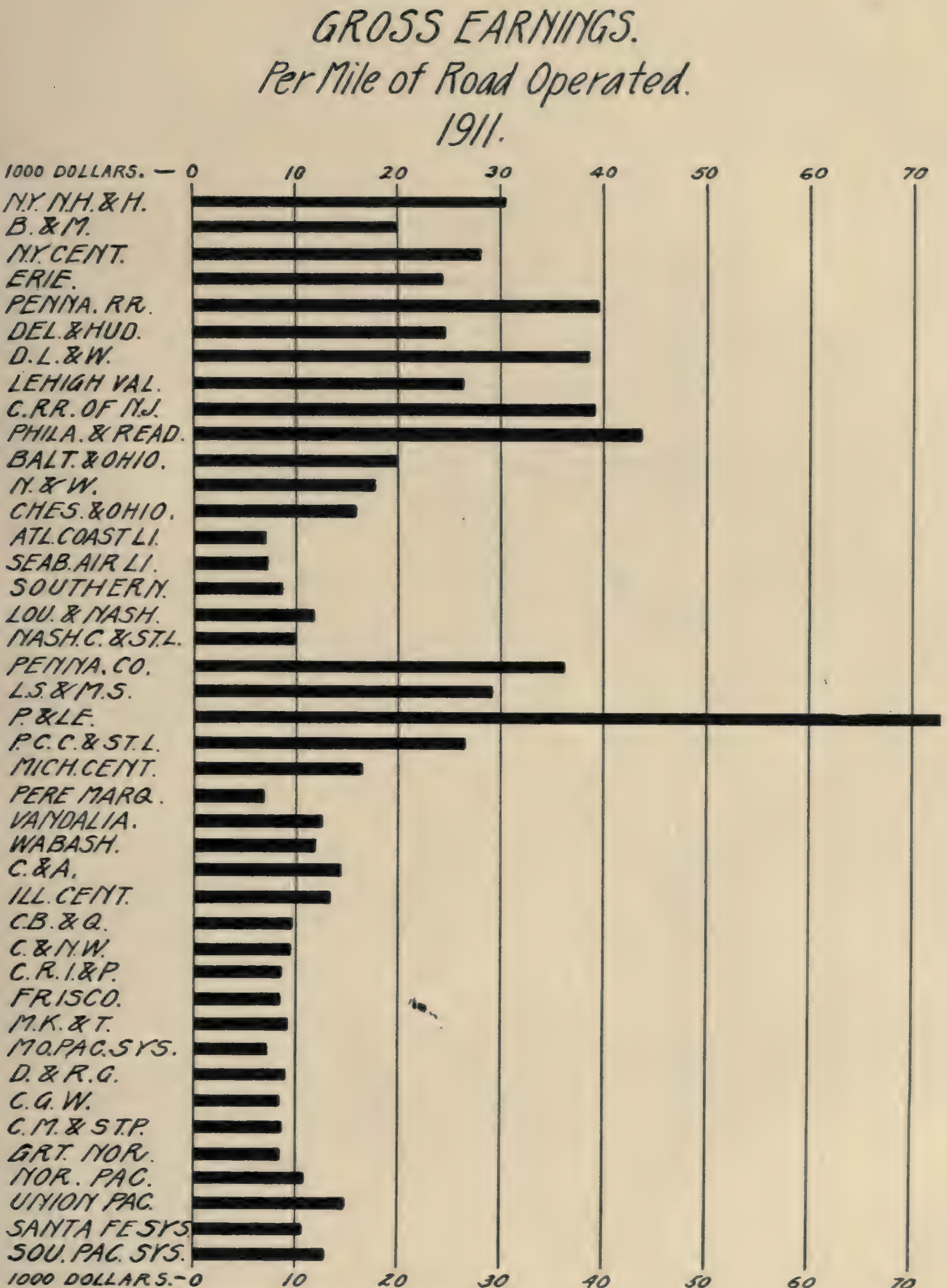

GROSS EARNINGS.
Per Mile of Road Operated.
1911.
1000 DOLLARS. — 0 10 20 30 40 50 60 70
N.Y. N.H. & H.
B. & M.
N.Y. CENT.
ERIE.
PENNA. RR.
DEL. & HUD.
D. L. & W.
LEHIGH VAL.
C. RR. OF N.J.
PHILA. & READ.
BALT. & OHIO.
N. & W.
CHES. & OHIO.
ATL. COAST LI.
SEAB. AIR LI.
SOUTHERN.
LOU. & NASH.
NASH. C. & ST. L.
PENNA. CO.
L.S. & M.S.
P. & L.E.
P.C.C. & ST. L.
MICH. CENT.
PERE MARQ.
VANDALIA.
WABASH.
C. & A.
ILL. CENT.
C.B. & Q.
C. & N.W.
C.R.I. & P.
FRISCO.
M.K. & T.
MO. PAC. SYS.
D. & R.G.
C.G.W.
C.M. & ST. P.
GRT. NOR.
NOR. PAC.
UNION PAC.
SANTA FE SYS.
SOU. PAC. SYS.
1000 DOLLARS.—0 10 20 30 40 50 60 70

FIG. 2

velopment also may lie in a large part beyond the terminals of the road that hauls the shipments attributable thereto.

The prosperity of a railroad bears a fairly direct relation to the people served, but these people may live beyond its territory. One road may run through a well-developed community, settled with thriving manufacturing towns which develop enough business to maintain the railroad on a paying basis, while another road traverses a sparsely populated country for hundreds of miles, where the revenue received from local business is practically nothing, and yet as this latter road constitutes a through line, connecting great commercial sections, its revenues may be the greater.

The accompanying chart, Fig. 3, shows the density of contiguous population per mile of road, obtained by computing the population of the counties traversed by each road and divided by the total miles of road operated, and illustrates comparative densities of population; while comparisons of population and of earnings appear in the text following.

The Chicago & Alton with a contiguous population of 4,504 per mile has gross earnings of $14,330 per mile; the Illinois Central, 1,568 people per mile and $13,-363 earnings; the Southern Pacific, 563 people and $13,000 earnings. The Baltimore & Ohio with 4,335 people and the Union Pacific with 531, have gross earnings of $19,880 and $14,850 per mile respectively. The Burlington and the Rock Island lie in the same general territory; the gross earnings of the former are $9,730 per mile and its population per mile 938; while the gross earnings of the latter are $8,708 and its population per mile 1,322.

The grades over which a railroad operates are exceedingly important when considering operating expenses, but have no direct bearing on the gross earnings.

The volume of business handled during a given period relative to length of road determines the "density" of the traffic. Statements furnished by railroads show the revenue ton miles of freight handled and the total number of passengers carried one mile, i. e., passenger miles for yearly periods.

The average number of revenue ton miles "per mile of road" can be used as the density of traffic to illustrate the volume of freight business. The average number of passenger miles "per mile of road" can be used to illustrate the volume of passenger business. Tabulated data and charts, Figs. 4 and 5, are submitted herewith for the same roads shown in Figs. 1 and 2, to permit of comparative study.

A road's traffic density figures for a series of years show at a glance the variations in business from year to year and in comparisons between roads this unit affords a concise index of the relative quantities of revenue traffic handled.

It is interesting in comparing various roads to consider together the grades, the gross earnings and the density of traffic.

First, let us compare three roads lying in the same general territory: the Pennsylvania Railroad, the New York Central and the Baltimore & Ohio.

	Freight Earnings	Freight Density
New York Central	$16,389	26.21
Pennsylvania Railroad	29,475	49.25
Baltimore & Ohio	15,253	26.39

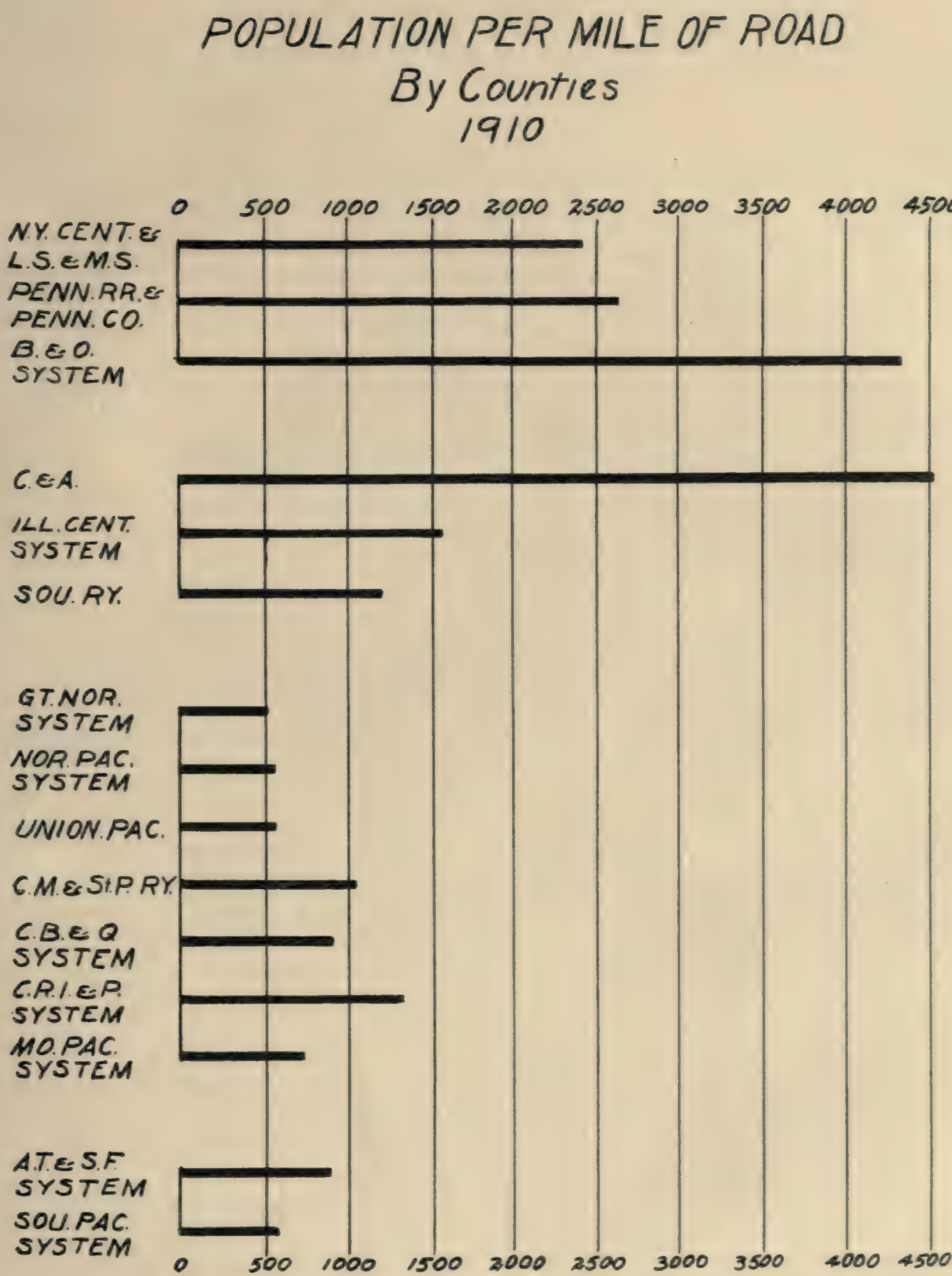

POPULATION PER MILE OF ROAD
By Counties
1910
0 500 1000 1500 2000 2500 3000 3500 4000 4500
N.Y. CENT. & L.S. & M.S.
PENN. RR. & PENN. CO.
B. & O. SYSTEM
C. & A.
ILL. CENT. SYSTEM
SOU. RY.
GT. NOR. SYSTEM
NOR. PAC. SYSTEM
UNION. PAC.
C.M. & St.P. RY.
C.B. & Q SYSTEM
C.R.I. & P. SYSTEM
MO. PAC. SYSTEM
A.T. & S.F. SYSTEM
SOU. PAC. SYSTEM
0 500 1000 1500 2000 2500 3000 3500 4000 4500

FIG. 3

Density of Traffic (Freight)
100,000 Revenue Ton Miles Per Mile of Road
1911

N. Y. N. H. & H.	10.88	P. C. C. & St. L.	29.08
B. & M.	10.54	Mich. Cent.	17.05
N. Y. Central	26.21	Pere Marq.	7.97
Erie	29.42	Vandalia	13.48
Penn. R. R.	49.25	Wabash	13.29
Del. & Hud	30.01	C. & A.	14.93
D. L. & W.	39.15	Ill. Cent.	14.64
Lehigh Valley	34.10	C. B. & Q.	7.84
C. R. R. of N. J.	34.83	C. & N. W.	7.04
Phil. & Read.	45.98	C. R. I. & P.	6.01
Balt. & Ohio	26.39	Frisco	5.45
Nor. & West.	34.46	M. K. & T.	5.12
Ches. & Ohio	30.09	Mo. Pac. Sys.	6.07
Atl. Coast Line	3.95	D. & R. G.	5.45
Seab. Air Line	4.20	C. G. W.	8.22
Southern Ry.	5.80	C. M. & St. P.	7.08
Lou. & Nash	11.08	Grt. Nor.	7.39
Nash. C. & St. L.	6.83	Nor. Pac.	8.06
Penn. Co.	46.37	Union Pac.	10.59
L. S. & M. S.	36.26	Santa Fe Sys.	7.03
P. & L E.	92.24	Sou. Pac. Sys.	6.55

The freight earnings per mile of road and the freight density (revenue ton miles per mile of road) go hand in hand: the freight densities on the New York Central and the Baltimore & Ohio are about equal and the earnings are nearly the same; the density of freight traffic on the Pennsylvania Railroad is nearly double that on the New York Central and the Baltimore & Ohio, with freight earnings in the same proportion.

When we consider the passenger traffic, a like relation between density of traffic and volume of earnings is to be seen:

	Passenger Earnings	Passenger Density
New York Central	$8,647	533
Pennsylvania Railroad	8,316	427
Baltimore & Ohio	3,430	179

The grades of the Pennsylvania Railroad and the Baltimore & Ohio are similar in nature and not very far from equal in extent, while the New York Central has decidedly lower grades than either.

Summed up, the ruling grades on various lines and branches of the systems are:

	Ruling Grade
New York Central	.20 to .86%
Pennsylvania Railroad	.36 to 1.75%
Baltimore & Ohio	.70 to 1.80%

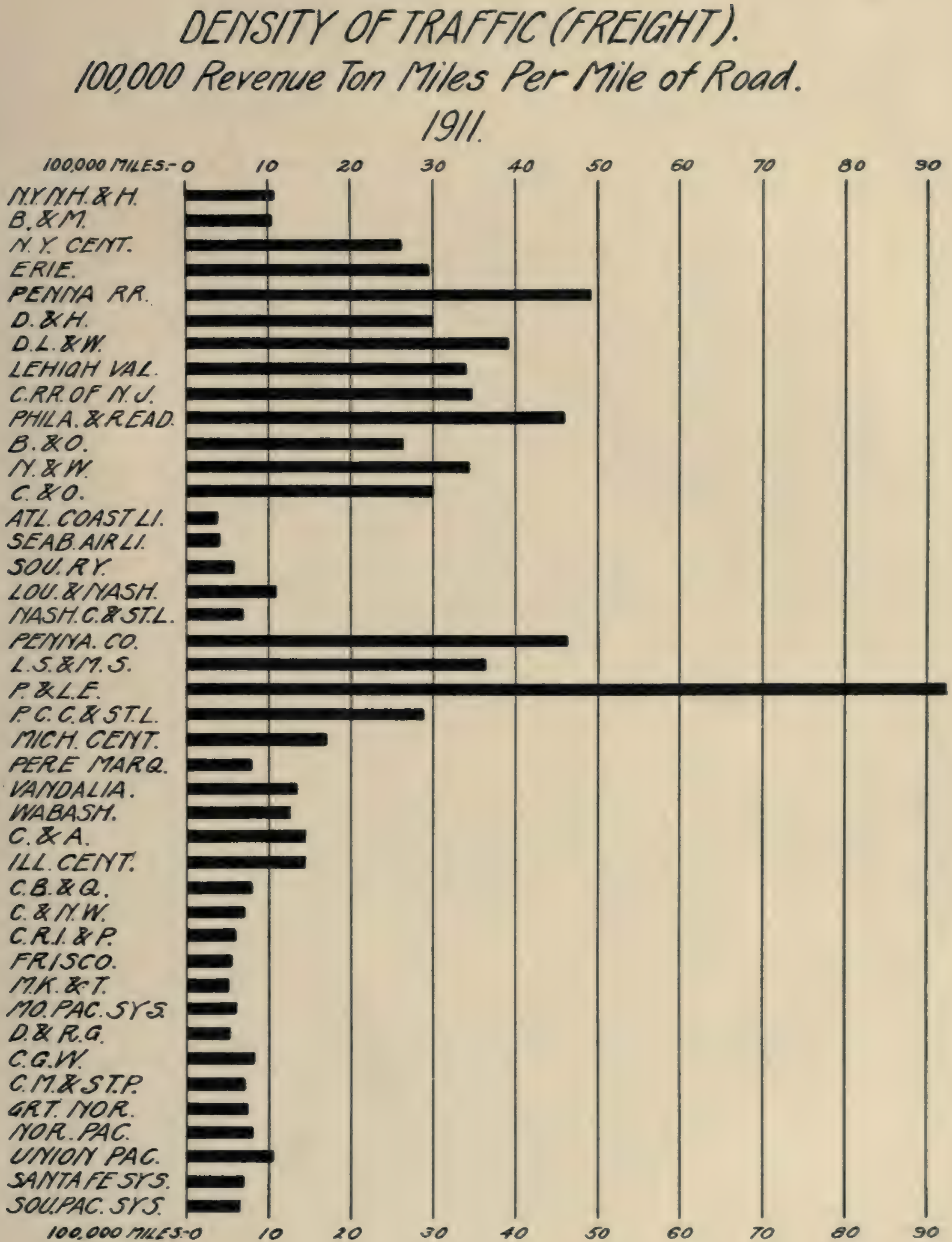

DENSITY OF TRAFFIC (FREIGHT).
100,000 Revenue Ton Miles Per Mile of Road.
1911.
100,000 MILES:- 0 10 20 30 40 50 60 70 80 90
N.Y.N.H.& H.
B.& M.
N.Y. CENT.
ERIE.
PENNA RR.
D.& H.
D.L.& W.
LEHIGH VAL.
C.RR. OF N.J.
PHILA.& READ.
B.& O.
N.& W.
C.& O.
ATL. COAST LI.
SEAB. AIR LI.
SOU. RY.
LOU.& NASH.
NASH.C.& ST.L.
PENNA. CO.
L.S.& M.S.
P.& L.E.
P.C.C.& ST.L.
MICH. CENT.
PERE MARQ.
VANDALIA.
WABASH.
C.& A.
ILL. CENT.
C.B.& Q.
C.& N.W.
C.R.I.& P.
FRISCO.
M.K.& T.
MO. PAC. SYS.
D.& R.G.
C.G.W.
C.M.& ST.P.
GRT. NOR.
NOR. PAC.
UNION PAC.
SANTA FE SYS.
SOU. PAC. SYS.
100,000 MILES:-0 10 20 30 40 50 60 70 80 90

FIG. 4

Density of Traffic (Passenger)

1,000 Passenger Miles Per Mile of Road

1911

N. Y. N. H. & H.	765	P. C. C. & St. L.	298
B. & M.	384	Mich. Cent.	208
N. Y. Central	533	Pere Marq.	95
Erie	305	Vandalia	142
Penn. R. R.	427	Wabash	152
D. & H.	168	C. & A.	212
D. L. & W.	607	Ill. Central	153
Leh. Valley	180	C. B. & Q.	129
C. R. R. of N. J.	513	C. & N. W.	136
Phil. & Read	404	C. R. I. & P.	130
Balt. & Ohio	179	Frisco	101
Nor. & West	98	M. K. & T.	122
Ches. & Ohio	122	Mo. Pac. Sys.	67
Atl. Coast Line	78	D. & R. G.	99
Seab. Air Line	72	C. G. W.	100
Southern Ry.	105	C. M. & St. P.	104
Lou. & Nash	111	Grt. Nor.	81
Nash. C. & St. L.	95	Nor. Pac.	127
Penn. Co.	319	Union Pac.	163
L. S. & M. S.	407	Santa Fe Sys.	127
P. & L. E.	462	Sou. Pac. Sys.	195

The Pennsylvania Railroad with similar grades to the Baltimore & Ohio has nearly double the freight traffic density and almost twice the earnings; the New York Central with its very low grades shows about the same freight earnings as the Baltimore & Ohio with its heavy grades.

The splendid showing of the Pennsylvania illustrates the force of a previous comment on industrial geography and the coal and iron trades.

Now to compare an eastern with a western road, each crossing a mountain range, and with equivalent grades:

	Freight		Passenger	
	Earnings	Density	Earnings	Density
Baltimore & Ohio	$15,253	26.39	$3,430	179
Union Pacific	10,303	10.59	3,189	163

The freight density on the Union Pacific is only 40% of that on the Baltimore & Ohio, while the earnings per mile are 67% as great, indicating much higher freight rates per ton mile on the Union Pacific. Passenger densities and earnings, however, show like ratios, indicating more nearly similar rates in this class of traffic on the two roads.

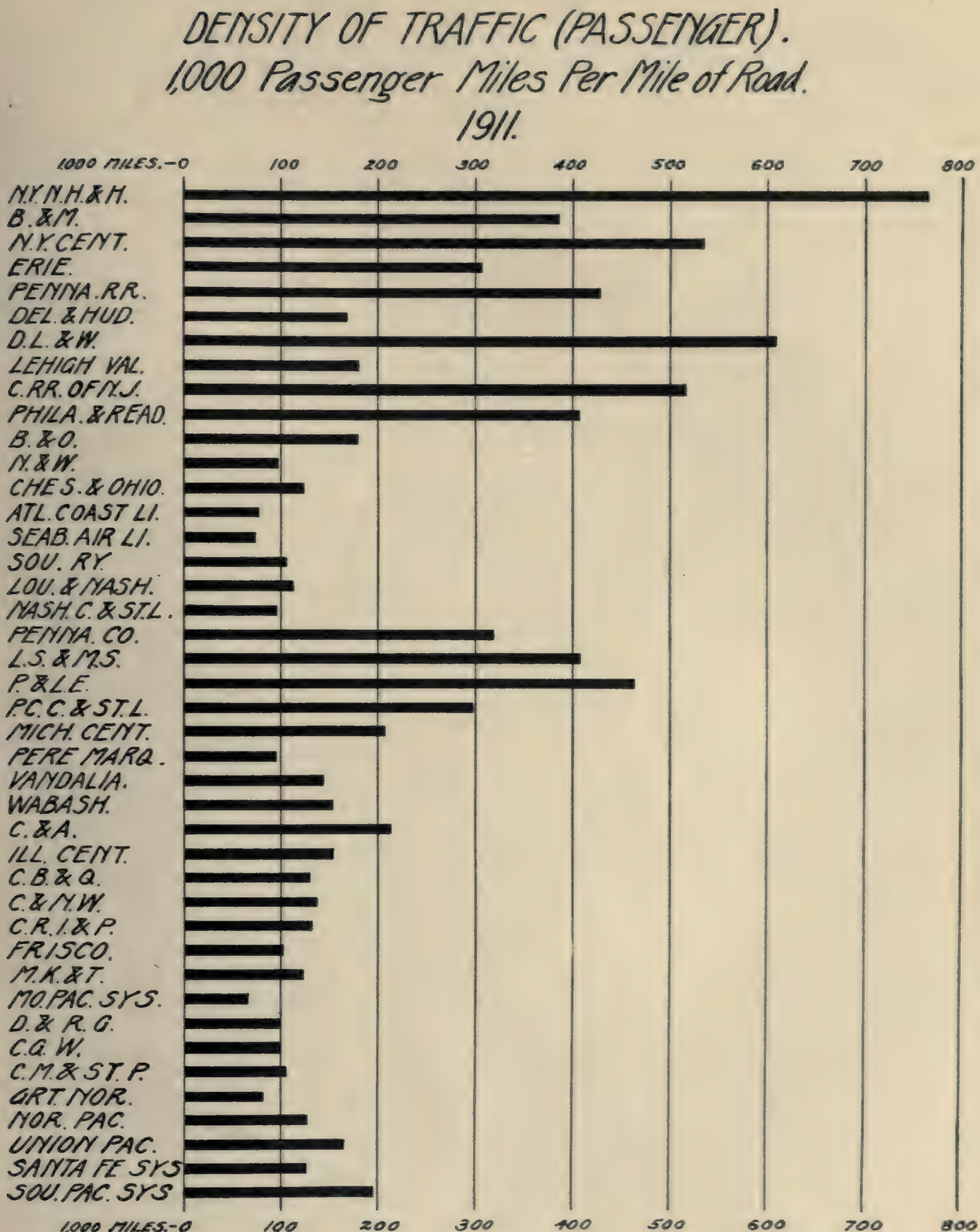

DENSITY OF TRAFFIC (PASSENGER).
1,000 Passenger Miles Per Mile of Road.
1911.
1000 MILES.–0
100
200
300
400
500
600
700
800
N.Y.N.H.&H.
B.&M.
N.Y.CENT.
ERIE.
PENNA.RR.
DEL.&HUD.
D.L.&W.
LEHIGH VAL.
C.RR.OF N.J.
PHILA.&READ.
B.&O.
N.&W.
CHES.&OHIO.
ATL.COAST LI.
SEAB.AIR LI.
SOU.RY.
LOU.&NASH.
NASH.C.&ST.L.
PENNA.CO.
L.S.&M.S.
P.&L.E.
P.C.C.&ST.L.
MICH.CENT.
PERE MARQ.
VANDALIA.
WABASH.
C.&A.
ILL.CENT.
C.B.&Q.
C.&N.W.
C.R.I.&P.
FRISCO.
M.K.&T.
MO.PAC.SYS.
D.&R.G.
C.G.W.
C.M.&ST.P.
GRT.NOR.
NOR.PAC.
UNION PAC.
SANTA FE SYS
SOU.PAC.SYS
1,000 MILES.–0

FIG. 5

To compare two western roads with similar grades, in like territory, let us take the Northern Pacific and the Great Northern:

	Freight		Passenger	
	Earnings	Density	Earnings	Density
Northern Pacific	$6,776	8.06	$2,702	127
Great Northern	5,947	7.39	1,840	81

Here we find that constant ratio between density of traffic and gross earnings which the parallelism of the roads and their unity of management would lead us to expect.

The foregoing examples illustrate the absence of direct relations between the extent of the population living along the line, the density of traffic, the physical characteristics and the gross earnings.

In the annual reports of railroad presidents, in the reports of the Interstate Commerce Commission and in the prominent financial manuals, particular stress is laid upon the ratio of operating expenses to gross earnings (see Fig. 6), on the assumption that this ratio is the fundamental basis of comparing efficiency in operation.

The fallacy of the assumption readily may be shown—if any presumption is needed to demonstrate the futility of using, for a measure of efficiency, the mathe-

OPERATING RATIOS

Per Cent. Operating Expenses to Gross Earnings

1911

N. Y. N. H. & H.	65.8%	P. C. C. & St. L.	72.0%
B. & M.	78.4	Mich. Cent.	75.0
N. Y. Central	74.0	Pere Marq.	80.4
Erie	64.9	Vandalia	77.3
Penn. R. R.	72.2	Wabash	74.8
Del. & Hud.	60.6	C. & A.	71.6
D. L. & W.	60.2	Ill. Central	71.9
Leh. Valley	62.1	C. B. & Q.	67.5
C. R. R. of N. J.	57.3	C. & N. W.	70.8
Phil. & Read	62.2	C. R. I. & P.	72.0
Balt. & Ohio	71.2	Frisco	66.7
Nor. & West	64.6	M. K. & T.	70.8
Ches. & Ohio	64.8	Mo. Pac. Sys.	82.1
Atl. Coast Line	64.7	D. & R. G.	68.2
Seab. Air Line	66.5	C. G. W.	74.8
Southern Ry.	67.8	C. M. & St. P.	69.1
Lou. & Nash	71.3	Grt. Nor.	61.3
Nash. C. & St. L.	75.3	Nor. Pac.	61.2
Penn. Co.	68.3	Union Pac.	53.2
L. S. & M. S.	71.7	Santa Fe Sys.	65.7
P. & L. E.	49.4	Sou. Pac. Sys.	60.1

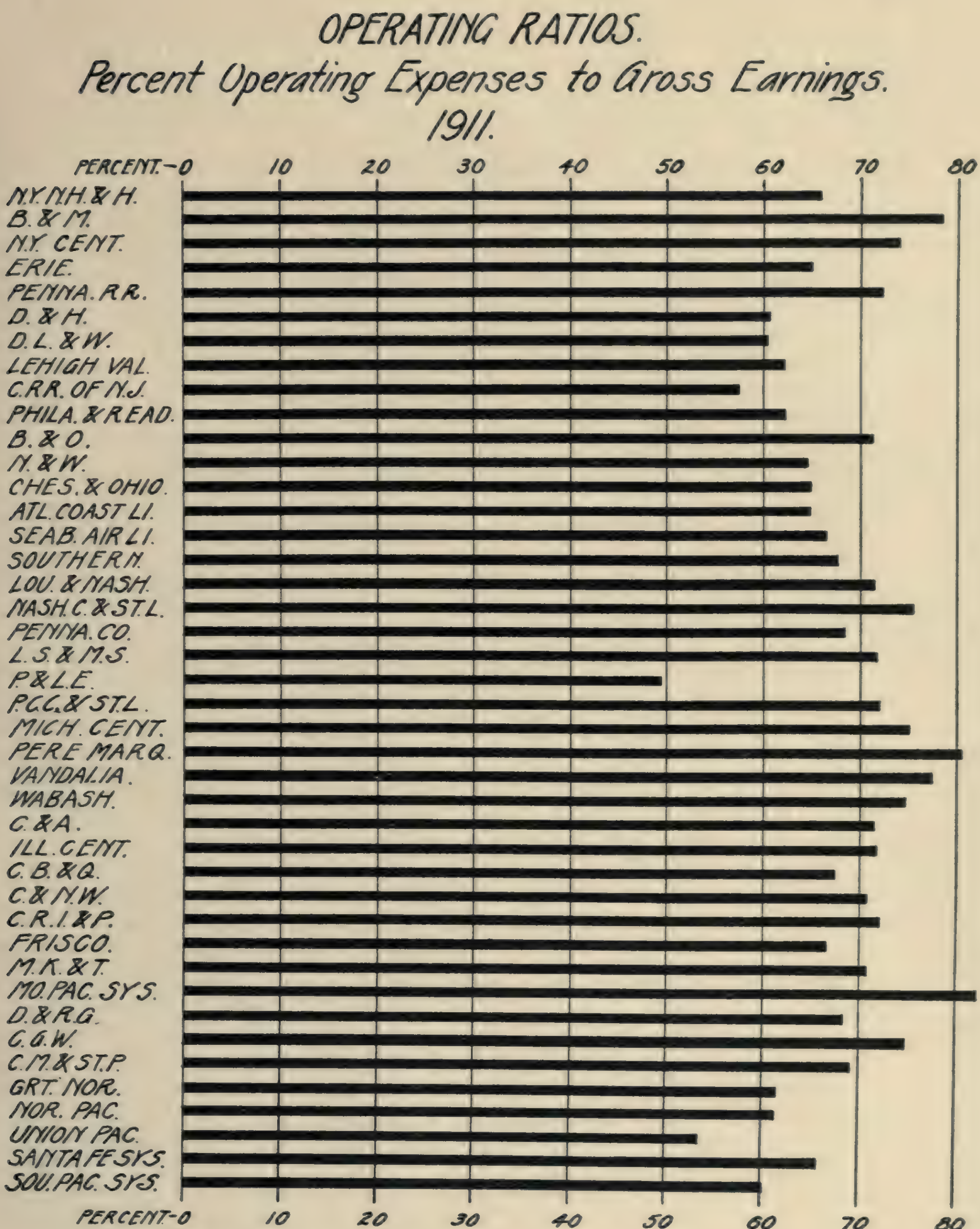

OPERATING RATIOS.
Percent Operating Expenses to Gross Earnings.
1911.
PERCENT.—0 10 20 30 40 50 60 70 80
N.Y.N.H.&H.
B.&M.
N.Y. CENT.
ERIE.
PENNA.R.R.
D.&H.
D.L.&W.
LEHIGH VAL.
C.R.R. OF N.J.
PHILA.&READ.
B.&O.
N.&W.
CHES.&OHIO.
ATL.COAST LI.
SEAB. AIR LI.
SOUTHERN.
LOU.&NASH.
NASH.C.&ST.L.
PENNA.CO.
L.S.&M.S.
P.&L.E.
P.C.C.&ST.L.
MICH. CENT.
PERE MARQ.
VANDALIA.
WABASH.
C.&A.
ILL.CENT.
C.B.&Q.
C.&N.W.
C.R.I.&P.
FRISCO.
M.K.&T.
MO.PAC. SYS.
D.&R.G.
C.G.W.
C.M.&ST.P.
GRT. NOR.
NOR. PAC.
UNION PAC.
SANTA FE SYS.
SOU.PAC. SYS.
PERCENT—0 10 20 30 40 50 60 70 80

Fig. 6

matical ratio between two quantities, one of which may vary independently of any factor of efficiency of operation—as when earnings rise because of higher rates on an unchanged tonnage traffic.

For several years past the Union Pacific has maintained its ratio of operating expenses to gross earnings at a lower figure than any other railroad in the United States. If the ratio of operating expenses to gross earnings is the all-important and fundamental basis of comparison, the Union Pacific is the most efficiently operated railroad in the country. This ratio was 59% for the fiscal year 1908 and 51% for the fiscal year 1910, the gross earnings during these periods showing an increase of 19.5% as compared with a 6.6% increase in operating expenses, all of which is further evidence of efficient operation on the above basis.

It is evident that the increase in gross earnings was the controlling factor in the reduction of the ratio of operating expenses to gross earnings.

Incidentally, analysis of the operating expenses during these two years reveals an increase of 31% in traffic expenses, and further investigation develops that the increase in gross earnings is to be attributed in great part to the ability of the traffic department to secure the transportation of commodities of higher class, for the revenue per ton in 1910 shows a marked increase over 1908—all of which illustrates the value of an able traffic department.

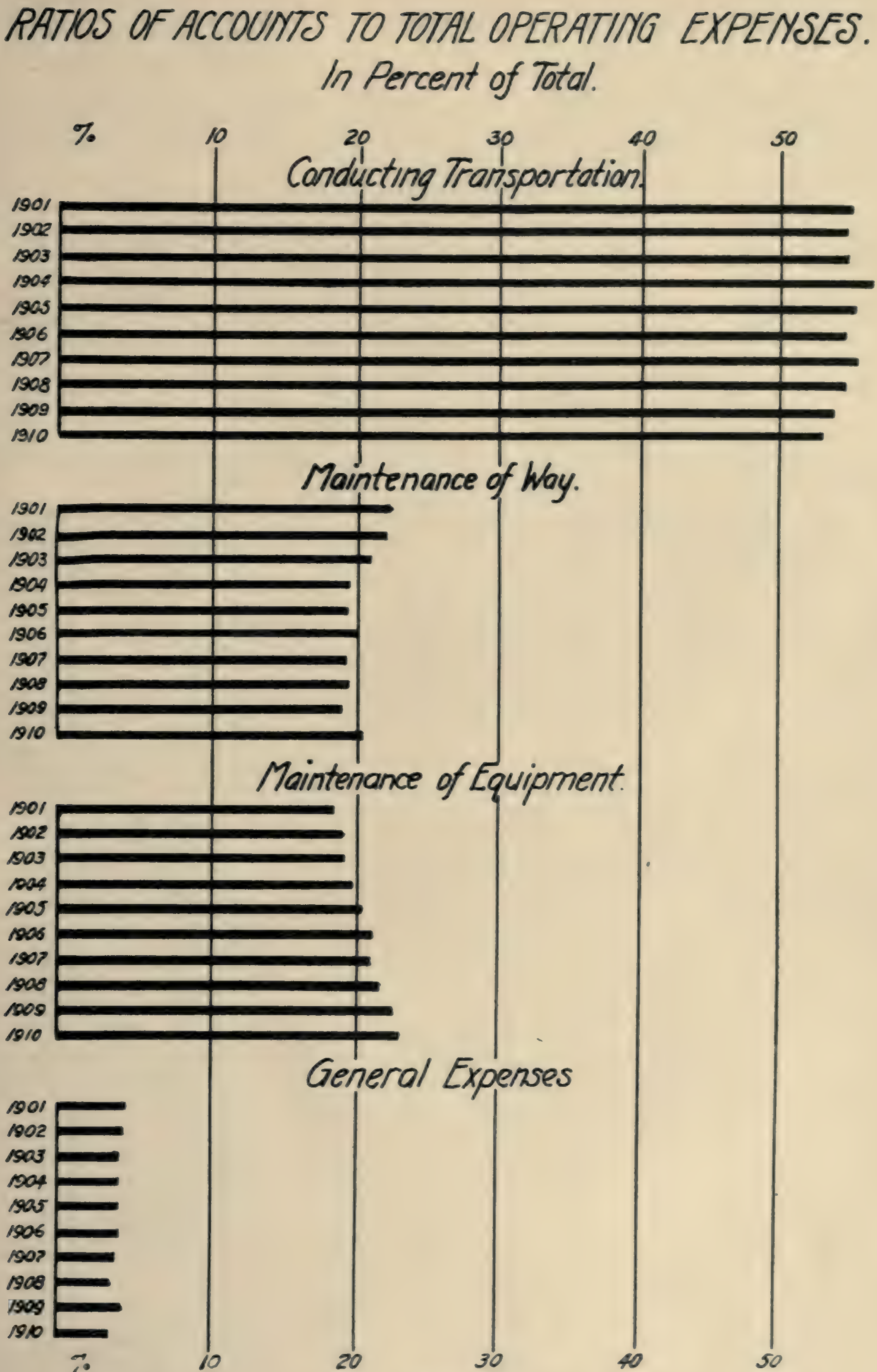
The Union Pacific had freight earnings of $11,033 per mile in 1910 and a freight density of 10.91; the Great Northern, a transcontinental competitor, had freight earnings of $6,693 per mile in 1910 and a freight density of 8.14. From the last figures it is clear that the Union Pacific handles an entirely different class of commodities than the Great Northern and consequently receives a higher average compensation, all of which has a marked effect on the gross earnings but has little effect on the cost of operating. If the remuneration per ton for freight was the same on the Great Northern as on the Union Pacific, the ratio of operating expenses to gross earnings of the former would be reduced from 61% to 52%; which compare with the 51% on the Union Pacific. A comparison of the profiles of the two roads suggests interesting deductions regarding their relative efficiency of operation.

Various comparisons with diverse results may be made between the several railroads shown in the diagram, and may be used to show clearly that the ratio of operating expenses to gross earnings is not a reliable basis of comparison of economy of operation.

The operating expenses of a railroad are dependent largely upon local conditions and must be separately analyzed in order to determine the efficiency of operation. The present railroad reports make five divisions of expenses, as follows:

1. Maintenance of Way and Structures,
2. Maintenance of Equipment,
3. Transportation Expense,
4. Traffic Expense,
5. General Expense.

The relative proportion of the four main divisions of expense (traffic expense being of a recent subdivision of transportation expense) to the total cost of opera-



RATIOS OF ACCOUNTS TO TOTAL OPERATING EXPENSES.
In Percent of Total.
%
10
20
30
40
50
Conducting Transportation.
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
Maintenance of Way.
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
Maintenance of Equipment.
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
General Expenses
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
%
10
20
30
40
50

FIG. 7

tion for the period between 1901 and 1910, shown graphically in Fig. 7, is as follows:

Classification of Operating Expenses in Per Cent of Total

Year	Maintenance of Way	Maintenance of Equipment	Conducting Transportation	General Expenses
1901	22.27%	18.63%	54.98%	4.12%
1902	22.26	19.13	54.67	3.95
1903	21.19	19.13	55.89	3.79
1904	19.52	19.97	56.67	3.84
1905	19.78	20.76	55.48	3.96
1906	20.29	21.39	54.43	3.86
1907	19.66	21.06	55.54	3.73
1908	19.73	22.06	54.89	3.32
1909	19.29	22.75	53.98	3.98
1910	20.22	22.66	53.36	3.76

As the operating expenses are dependent upon operating conditions, the subsequent chapters present analyses of detailed operating costs, illustrating the question of efficiency.

Maintenance of Way and Structures

CHAPTER II.

The major portion of any railway's initial cost and capitalization is presented in the road and not in the rolling equipment. The road, moreover, represents approximately as large an annual expenditure for maintenance as does the rolling equipment, and though it does not appear in the accounts, an even larger sum for depreciation. Not only this, but the continual improvements in transportation methods and standards entail the sinking of larger capital sums annually in betterments than is the case with the equipment.

No one department of a railway's operation has such potent effect upon the whole character and results of that operation as the department having jurisdiction over maintenance of way and structures, including therein those activities of the railway charged with the physical betterment of the way, and with the provisions of additional facilities. The train load is more a function of the grade than it is the size of the locomotives. Grade, therefore, is the principal cause affecting cost of transportation and is dependent largely upon topography. Topography also determines the cost of way so far as it relates to engineering but not so far as it relates to ground values. Tunnels, bridges and terminals involve capital expenditures, running into the millions per mile, and very large traffic results must accrue to warrant any considerable expenditures for this kind of mileage.

Curvature, also determined by topography, is an obstruction to fast and economical operation, similar to, but not equally as large as, that of grade. Outside clearances, determined by tunnel sections, overhead bridges and by projections into the right-of-way area, have also a profound effect upon the cost of transportation as they determine locomotive and car capacities. Span and strength of bridges and culverts, solidity of fills, ballast and track, also affect transportation capacity, placing limits on axle loads, total locomotive weights, and speeds.

It needs no demonstration to show that the locomotive and train crew will handle a larger train upon a level road than upon a hilly or mountainous one, that the train will run faster, that less fuel will be burned, that the wear and tear on the locomotive and cars (brakes, wheels, etc.), will be less.

Stated in another way, to attain the same train load or speed upon the road with a heavy grade as upon the level, a larger and more costly locomotive, burning more fuel, must be used, and the draft gear and the cars otherwise strengthened to withstand the greater shocks. The net result in either case is increased transportation cost due to grade.

Every railroad man knows that a curve can be designed for one speed of train only and that it either has too great or too little elevation of the outer rail for speeds less or greater than that for which it was designed.

This restriction on speed, and also train resistance due to curvature, increases the size of the motive power and the time necessary to move a train over a given mileage.

Closely connected with the problem of curvature is that of alignment. A short direct, straight and level line will permit of a denser and more economical traffic movement than a longer tortuous route. But with the given probable increase in traffic requirements there is a definite point where the relocation of a road, to avoid curves and grades will not pay. An example of such a condition is found in the case of the Lucin cut-off across Salt Lake.

The width, height, and length of a car depend upon the clearance of the road. If we contrast the load clearances usually found in this country with those obtaining in England, we find that where our widths run from 10 to 12 feet, their maximum is about 9; where our heights are from 15 to 18 feet above the rail; their maximums are between 12 and 13. This leaves a possible load area above the platform of the cars of approximately from 60 to 70 square feet in British practice as compared with from 110 to 150 square feet in American practice, giving about 100% more load per foot of length of car on American roads as compared with British. Thus it is that the British "goods wagon" has a capacity averaging barely one-fourth the capacity of our eight-wheeled freight car, a restriction in carrying capacity per unit length of train imposed chiefly by the much smaller clearances obtaining abroad. In this respect western roads in the United States, roads generally in new countries, and roads particularly in flat plains regions, have a great advantage over roads in older, more settled or more mountainous regions.

Any attempt to increase the clearance through a settled community or over a mountainous line, tends to become prohibitive in expense and almost insurmountable in physical obstacles.

Bridges are designed for a maximum load and speed factor; loads and speeds above these used in the factor of design produce stresses in the structure exceeding safe working limits and in so far as the bridges cannot be strengthened to support a heavier load or higher speed than that for which they were designed, they act as a hindrance to the movement of traffic by economical train loads and speeds. Not long ago, 40,000 pounds was the unit locomotive axle load used in Cooper's formula; driving wheel axle loads exceeding 50,000 pounds are usual current practice now, and loads between sixty and seventy thousand pounds are not uncommon. It is obvious that a line built or rebuilt to-day for heavy traffic should be equipped with bridges and culverts capable of supporting an axle load not far short of 100,000 pounds, if future needs, within the economical life of the structures, are to be provided for.

What is true of bridges is in large measure equally true of track from the ball of the rail to the road bed. The wearing surface of the rail must possess sufficient hardness to avoid metal flow under the greatest wheel pressures; to wear such a length of time under dense traffic as not to make frequency of renewals an uneconomical burden on operation. The rails must be so stiff as not to fail under the greatest shocks, both vertical and side, experienced in practice, and must be supported at sufficiently frequent intervals as not to bend, and upon sufficient area of sleepers and ballast as to eliminate the tendency of crushing or settling.

Without at this time going into such details as kind of joints, rails, fastenings, character of ballast, types of bridges, etc., that are desirable under modern operating tendencies, it is evident from the foregoing that the engineering practice of a railway is of the greatest importance in its influence upon the whole economy of operation and in the end upon financial return.

Although the prime importance of the relation of engineering problems to profitable railway location and operation is well recognized, the actual cost of maintenance

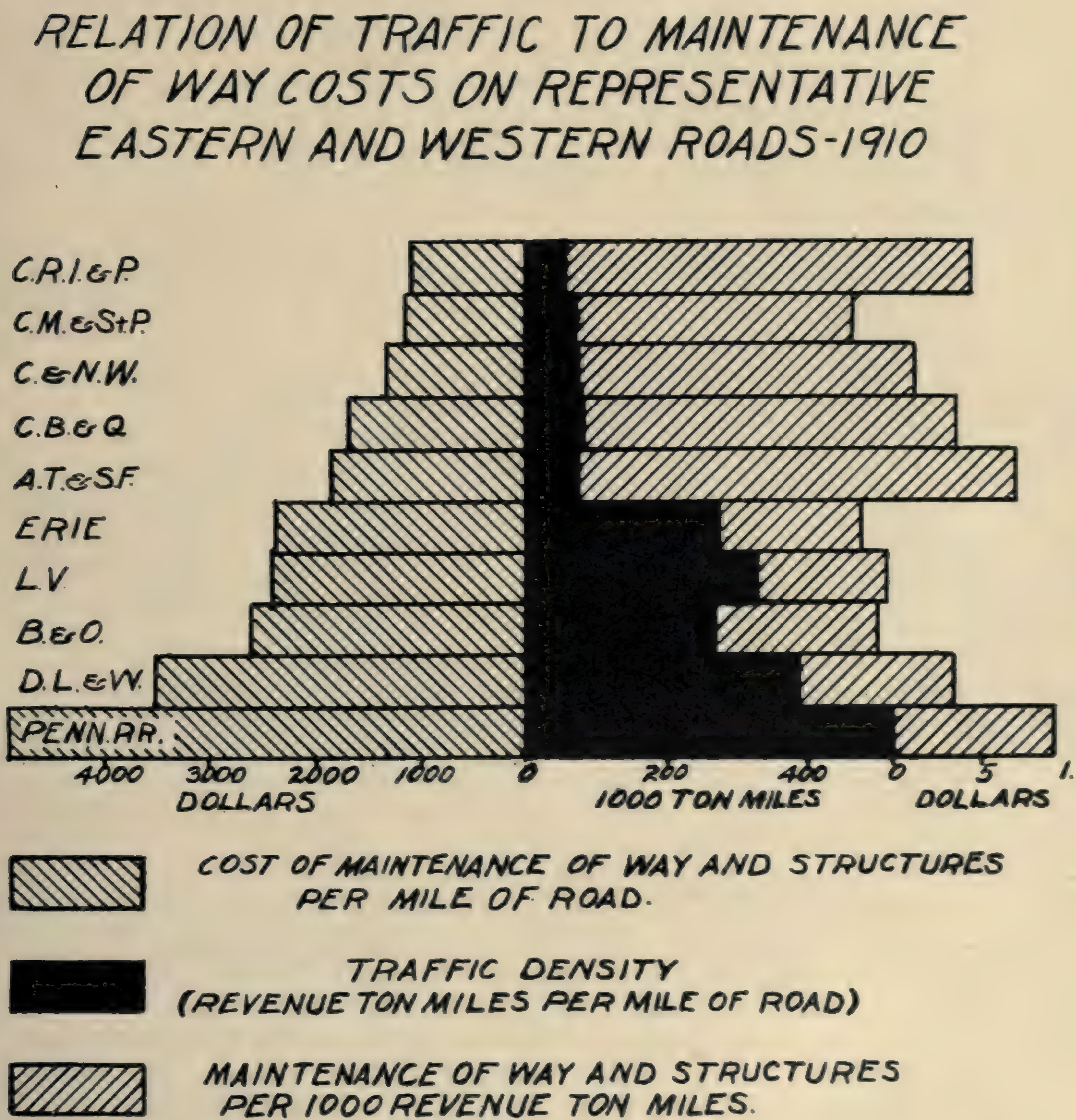


FIG. 8

of way and structures does not vary with the traffic, or does not bear nearly so constant a ratio to traffic density as in the case with maintenance of equipment and transportation expenses.

The relation the expenditure for maintenance of way and structures for a given period, bears to the geographical mileage and the volume of business, is illustrated in Fig. 8, showing this information graphically for ten representative railways.

This diagram shows the variation in traffic conditions among the various railroads, particularly as between eastern and western roads. It also shows that comparisons of maintenance costs per mile of road, which do not take into account the traffic density are valueless, although this is the unit usually employed by investors and railroad men in judging as to upkeep of the property.

Roads with two or more tracks must spend more for maintenance of way per mile of road than those having only single track; roads handling a heavy volume of business, as reflected by the traffic density and the average train load will need to spend more for maintenance of track and also equipment than those doing lighter business.

A study of Fig. 8 reveals that maintenance does not vary directly in proportion to traffic density, although it might seem logical to suppose that such would be the case. It seems probable that the earnings or the financial conditions determine the amount of maintenance expenditure.

Comparisons covering a period of years indicate no definite conclusions can be reached with reference to the maintenance of way expenditures for any one year. Such studies to be valuable must cover an extended period.

In Fig. 9 is a graphical description of the percentage of maintenance of way and structures to the total operating expenses on the Lackawanna and the Union Pacific for the 10 years ending 1910. The relation the yearly expenditures bear to the 1901 record is also shown, the increases and decreases indicating an exceedingly wide variation.

In judging the maintenance of way and expenditures of a given line, the physical characteristics must in all cases come in for careful consideration. It is manifestly unfair to compare the maintenance of way costs (per mile of road) on the Union Pacific with the Chicago & Alton. The Chicago & Alton runs through a country where heavy rains are frequent, causing the ties to decay in a short time. The ballast used is gravel or cinders, either of which is none too good and easily washed out, resulting in a heavy maintenance cost. Some of the line is ballasted with crushed stone which is excellent ballast, but very expensive.

On the other hand, the Union Pacific runs through a comparatively dry or semi-arid country where the ties seldom are removed on account of decay and the ballast is the very best and cheapest, it being disintegrated granite from Sherman Hill near Cheyenne, Wyoming. This ballast is of the best quality and is procured at a low cost.

The average cost of maintenance of way for the past ten years is $1,260 per mile on the Union Pacific, as against $1,380 for the Chicago & Alton. This does not necessarily mean that the track of the Union Pacific is not kept up as well as the track of the Chicago & Alton.

PERCENTAGE MAINTENANCE OF WAY AND STRUCTURES TO TOTAL OPERATING EXPENSE TOGETHER WITH INCREASE OR DECREASE COMPARED WITH 1901.

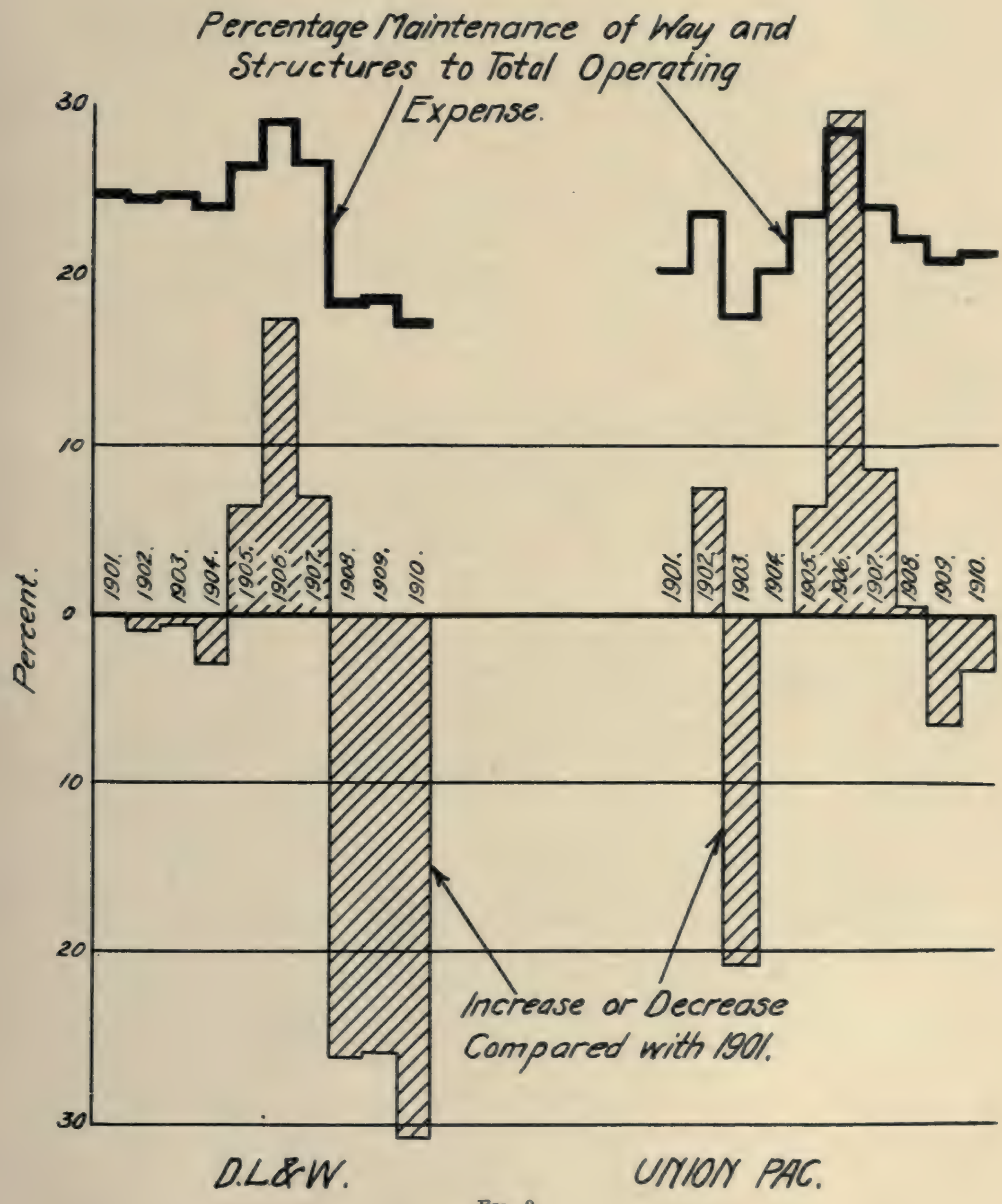


Fig. 9

If a railroad is obliged to maintain expensive terminals, it should spend more than a railroad of the same type in other respects, which does not have these characteristics. To compare two roads in the same territory; the St. Joseph & Grand Island has very inexpensive terminals, while the Kansas City Southern maintains elaborate terminals at Kansas City and particularly at Port Arthur, Texas. The St. Joseph & Grand Island spent in 1908 only $475 per mile for maintenance of way, and averaged $700 per mile for the past ten years, yet this small amount has apparently been sufficient to maintain the property at as high a standard as has been necessary and relatively is probably as good as the Kansas City Southern with an average for nine years of a little more than $1,000 per mile.

The maintenance of way expenditures per mile on a ten years' average vary all the way from $700 on the St. Joseph & Grand Island to over $10,000 on the Pittsburg & Lake Erie. This enormous difference is explainable when we realize that all of the mileage operated on the Pittsburg & Lake Erie has two or more tracks while the St. Joseph & Grand Island operates only a single track. Again the Pittsburg & Lake Erie has a freight density of nine million revenue ton miles per mile of road and an average revenue freight train load of 1200 tons as compared to the St. Joseph & Grand Island with a freight density of less than ⅓-million ton miles per mile of road and a revenue freight train load of 220 tons.

The usual reports of railroad operations as published, show operating costs per mile of road for one period compared with another period (month, year, or decade), and unless the reader is familiar with the road in question, the deductions drawn from a perusal of the figures are very unsatisfactory.

The Atchison, for example, expended $1,835 per mile of road for maintenance of way and structures in 1910, as compared with $793 in 1901. Without a knowledge of the influencing conditions, the volume of business, etc., for these two periods, the above figures would indicate the expenditures in the year 1910, were exhorbitant as compared with 1901, and a careful analysis of the entire situation is necessary in order to determine a relative comparison. A study of the business handled develops the freight density more than doubled during the above mentioned period, thus indicating a very heavy increase in the volume of business. This fact, together with a 35% increase in the weight of locomotives and 25% increase in capacity of freight cars, has resulted in a proportional growth to the wear and tear of track and presents the matter in a different light.

It is therefore evident, when judging maintenance of way expenditures that many items must be taken into consideration other than the mileage operated and the gross earnings. Far more important are the character and volume of business, the topography of the country and the weight of equipment, all of which must be given due consideration.

The following table is submitted showing the maintenance costs "per mile of road" for 20 representative railroads for the years 1908, 1909, 1910 and 1911 and illustrated in Fig. 10.

MAINTENANCE OF WAY AND STRUCTURES

Per Mile of Road.

	1908	1909	1910	1911
N. Y. N. H. & H.	$2923	$2729	$3490	$3422
N. Y. Central	3408	3032	3603	3813
Penn R. R.	4456	4135	4998	4873
Erie	2915	1988	2391	2589
B. & O.	2728	2200	2630	2319
D. L. & W.	4032	3713	3536	4350
Lehigh Valley	2417	2246	2416	2532
N. & W.	1801	1716	1923	2160
Atl. Coast Line	867	797	837	873
Southern	946	832	941	1061
Lou. & Nash	1441	1184	1780	1986
L. S. & M. S.	3837	3328	3753	4768
P. & L. E.	7380	7464	9069	8783
C. B. & Q.	1595	1450	1740	1367
C. & N. W.	1056	1099	1412	1292
Frisco	943	994	1151	1059
Union Pac.	1688	1490	1681	1668
Santa Fe Sys.	1534	1336	1835	1591
Sou. Pac. Sys.	1993	1591	1692	1653
Grt. Northern	1502	1310	1623	1321

The extremes are the Atlantic Coast Line with an annual expenditure of $797 in 1909, and the Pittsburg & Lake Erie with $9,069 in 1910, a difference of 1,036%.

For the purpose of further illustrating the erroneous conclusions possible when the unit "per mile of road" is used, these maintenance costs for the same railroads are also shown with the locomotive tractive mile as the comparative unit.

This unit is the only one available which combines the volume of business and the weight of the equipment, since it is determined by taking the average locomotive tractive force in pounds and multiplying by the total locomotive miles. (This product is divided by 1,000,000, to bring the unit within comprehension.)

The maintenance costs per locomotive tractive mile are shown herewith, Fig. 11, for the same roads and the same periods as shown in Fig. 10, and comparisons between the two tables are both interesting and instructive.

From these figures the annual cost per tractive mile varies from $4.78 on the B. & O. in 1911 to $13.78 on the Great Northern in 1908, a variation of 188%.

While these comparisons serve to illustrate that the generally accepted unit "mile of road" is valueless, the relative comparisons in Fig. 11, cannot be considered as conclusive.

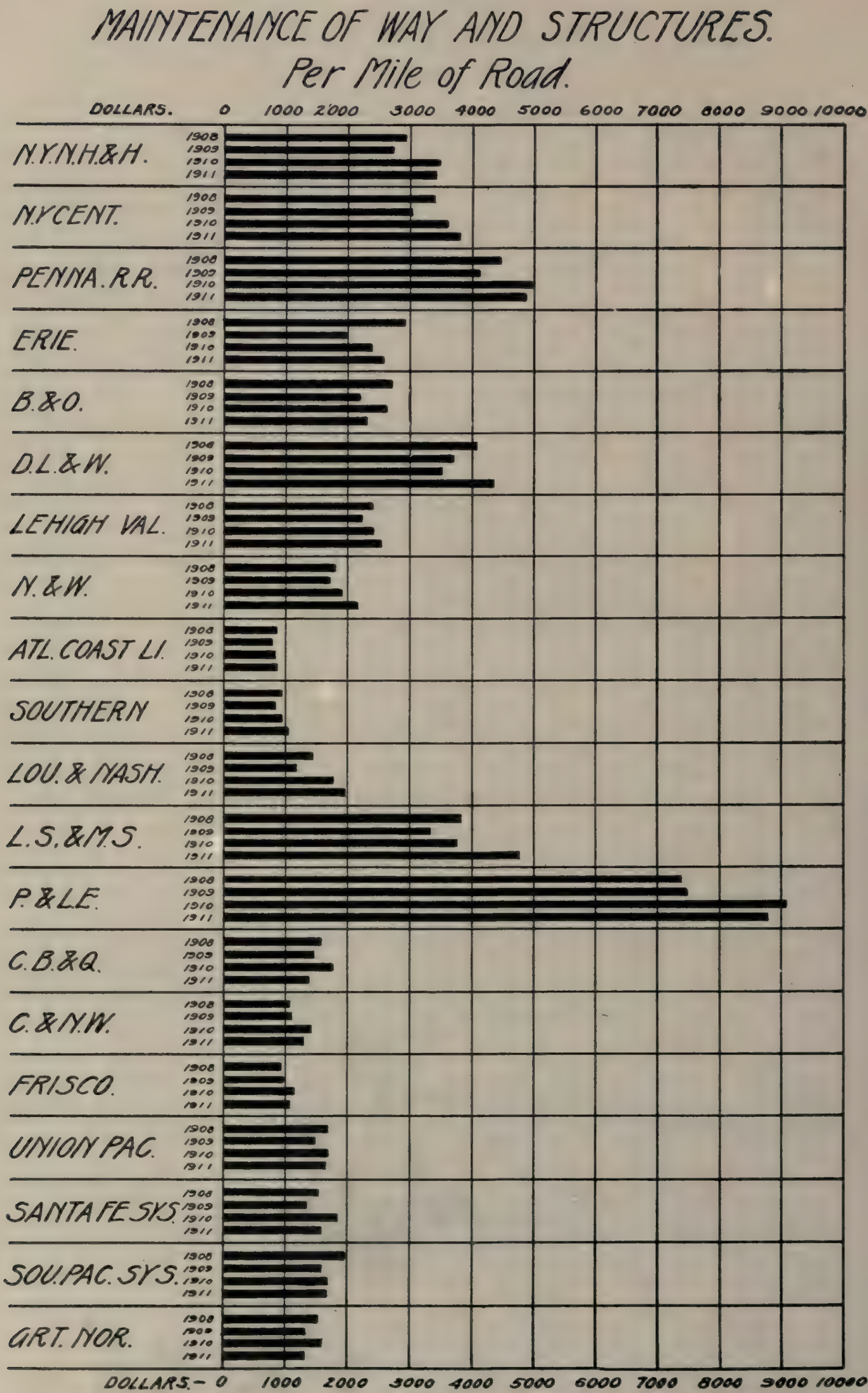

MAINTENANCE OF WAY AND STRUCTURES.
Per Mile of Road.
DOLLARS. 0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000
N.Y.N.H.&H.
N.Y.CENT.
PENNA. R.R.
ERIE.
B.&O.
D.L.&W.
LEHIGH VAL.
N.&W.
ATL. COAST LI.
SOUTHERN
LOU.&NASH.
L.S.&M.S.
P.&L.E.
C.B.&Q.
C.&N.W.
FRISCO.
UNION PAC.
SANTA FE SYS.
SOU.PAC.SYS.
GRT. NOR.
1908
1909
1910
1911
DOLLARS.– 0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000

Fig. 10

Maintenance of Way and Structures

Per Locomotive Tractive Mile.

	1908	1909	1910	1911
N. Y. N. H. & H.	$ 8.48	$9.07	$10.57	$10.02
N. Y. Central	6.15	5.34	5.94	6.09
Penn. R. R.	6.19	6.22	6.52	6.33
Erie	7.02	4.89	5.48	5.99
B. & O.	6.22	5.48	5.77	4.78
D. L. & W.	6.70	6.72	6.21	7.33
Lehigh Valley	6.00	6.06	5.70	5.79
N. & W.	5.19	5.29	4.91	5.36
Atl. Coast Line	9.72	9.48	9.28	9.10
Southern	5.79	5.35	5.50	5.84
Lou. & Nash	7.33	6.39	8.62	9.19
L. S. & M. S.	7.11	6.39	5.93	7.24
P. & L. E.	8.69	8.70	7.46	8.88
C. B. & Q.	12.70	11.73	12.55	9.70
C. & N. W.	7.97	8.03	8.58	7.72
Frisco	7.39	7.69	7.97	7.01
Union Pac.	9.46	8.25	8.43	8.34
Santa Fe Sys.	9.58	8.80	10.44	8.87
Sou. Pac. Sys.	12.27	10.81	10.33	10.03
Grt. Nothern	13.78	13.67	12.31	10.29

The topography of the country and the character of the traffic determining the speed of trains, and the extent of terminal facilities, must be given full consideration. The influence of capital expenditures for additions and betterments are also of consequence, since these expenditures involve the policy of the management as regards future needs.

The principal investment in a railroad is in its roadway, and in building, rebuilding, or extending a road such a policy should be adopted as will balance growing traffic capacity and lowered operating cost against larger fixed and depreciation charges. This rule applies also to terminal facilities and through traffic links involving expensive construction.

A study of the maintenance of way and structures expenditures for comparative purposes must be sufficiently comprehensive to include all influencing factors. It must necessarily cover an extensive period and separately consider the component items of this division of operating expenses. Such analytical study is, however, left for future consideration.

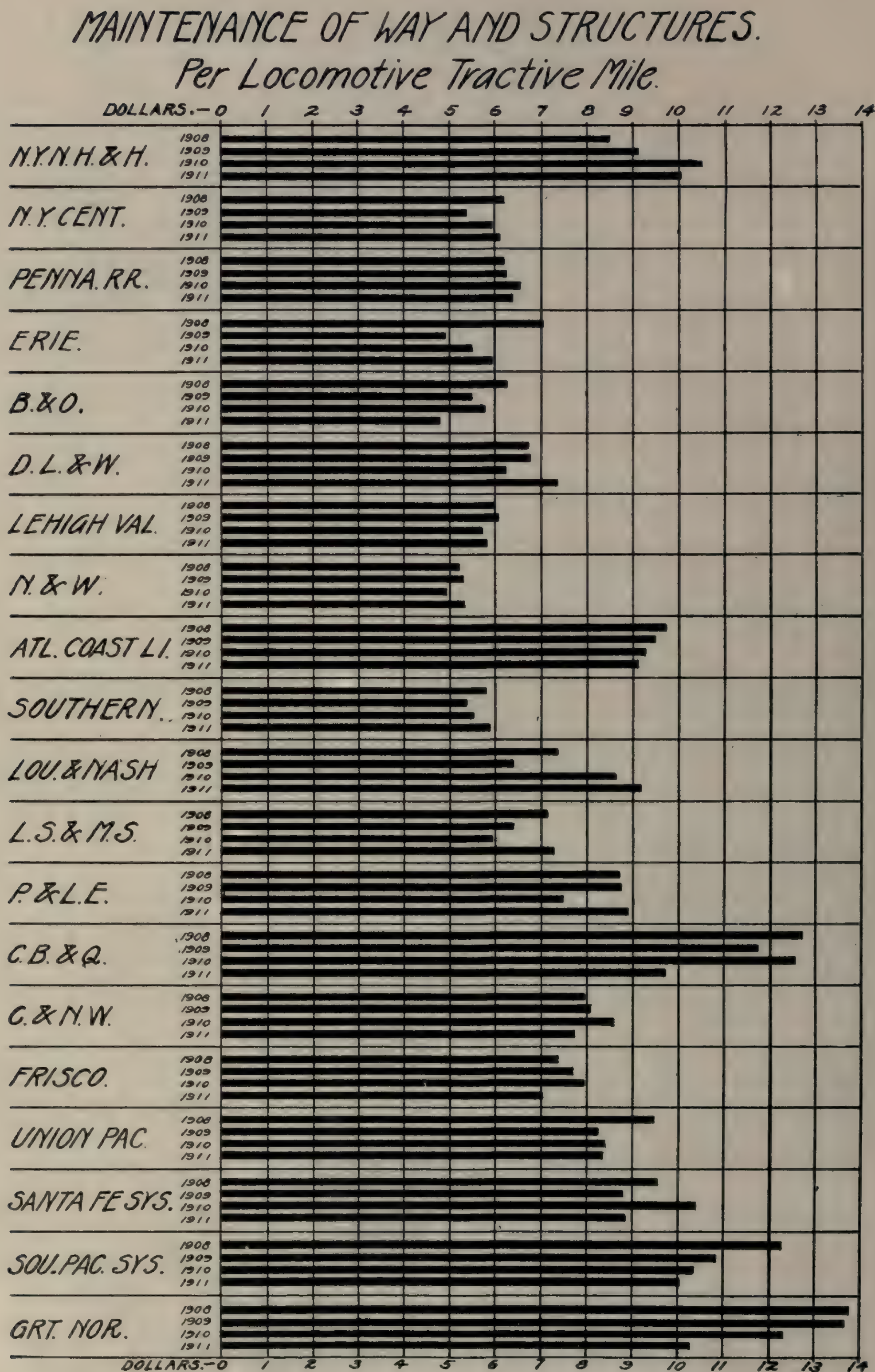

MAINTENANCE OF WAY AND STRUCTURES.
Per Locomotive Tractive Mile.
DOLLARS.—0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
N.Y.N.H.&H.
N.Y.CENT.
PENNA.RR.
ERIE.
B.&O.
D.L.&W.
LEHIGH VAL.
N.&W.
ATL. COAST L.I.
SOUTHERN..
LOU.&NASH
L.S.&M.S.
P.&L.E.
C.B.&Q.
C.&N.W.
FRISCO.
UNION PAC.
SANTA FE SYS.
SOU.PAC. SYS.
GRT. NOR.
1908
1909
1910
1911
DOLLARS.—0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

FIG. 11

Maintenance of Equipment

CHAPTER III.

In point of magnitude, maintenance of equipment ranks second among the items entering into operating expenses. In 1901, it ranked third. The relative proportion of the main divisions of expense averaged for the large railroads in the years 1901 and 1910, as follows:

	1901	1910
Maintenance of Way and Structures............	22.3%	20.2%
Maintenance of Equipment.....................	18.6	22.7
Conducting Transportation.....................	55.0	53.4
General Expense..............................	4.1	3.7

Of all the main divisions of expense shown above, maintenance of equipment is the only one which has increased in ratio to total operating expense during the ten-year period ending with 1910. This increase is very marked and in strong contrast to corresponding decrease in the other three main divisions of operating expense.

The steadily increasing cost of maintenance of equipment during the past decade, as reflected by the above figures, is as conspicuous as the corresponding reductions in the other three items of operating expense. The component charges entering into maintenance of equipment, such as labor, material, etc., are also common to the other operating items. The assertion therefore that higher labor and material costs are responsible for the increasing ratio in the cost of maintenance of equipment to total operating expense does not hold when the same test is applied to conducting transportation and maintenance of way.

That definite relations exist between increasing cost of maintenance of equipment and decreasing transportation charges is clearly reflected through analysis of conditions. Locomotives and cars are growing larger in capacity, obviously reducing the number of power units required to handle a given amount of traffic.

The ratio of maintenance of equipment to total operating expense on the large roads for the past ten years is shown in accompanying table and graphically in Fig. 12. The per cent. increase in maintenance charges to the total compared with the year 1901 are also included with similar information for four representative roads.

Ratio Maintenance of Equipment to Operating Expense.

Year	All Roads	Atchison	Sou. Pac.	B. & O.	P. R. R.
1901..........	18.6%	21.3%	12.2%	19.7%	23.6%
1902..........	19.1	24.4	19.3	20.5	23.4
1903..........	19.1	22.8	20.8	21.5	24.2
1904..........	20.0	24.0	21.9	24.0	23.7
1905..........	20.8	24.6	23.6	24.3	25.8
1906..........	21.4	22.8	23.8	25.0	26.0
1907..........	21.0	21.3	21.6	24.2	26.0
1908..........	22.1	24.6	20.6	23.2	26.1
1909..........	22.8	25.2	23.0	22.3	26.1
1910..........	22.7	23.0	22.7	26.0	26.0

Per cent. Increase in Maintenance of Equipment to Operating Expense Compared with the Year 1901.

Year	All Roads	Atchison	Sou. Pac.	B. & O.	P. R. R.
1902..........	2.7%	14.5%	6.6%	0.4%	00.0%
1903..........	2.7	7.0	14.9	9.1	.01
1904..........	7.5	12.7	21.0	21.8	.04
1905..........	11.6	15.5	30.4	23.3	9.5
1906..........	15.0	7.0	31.5	27.0	10.2
1907..........	12.9	00.0	30.4	23.0	10.2
1908..........	18.8	11.7	23.7	17.7	10.6
1909..........	22.6	18.2	39.2	13.2	10.6
1910..........	22.0	8.0	25.4	37.0	10.2

In 1901 equipment on the large roads was maintained for 18.6 per cent. of total operating expense. During the following decade the percentage increased steadily, reaching 22.7 per cent. in 1910, an increase of nearly 25 per cent. over the figure in 1901. The same conditions in varying degree are reflected in the records of the representative railroads shown. The Southern Pacific Company maintained their equipment in 1910 for 22.7 per cent. of total operating expense, an increase of 25.4 per cent. over 1901; similarly the Atchison for 23 per cent., an increase of 8.0 per cent.; the Baltimore & Ohio for 26 per cent., an increase of 32 per cent., and the Pennsylvania Railroad for 26 per cent., an increase of 10.2 per cent. over 1901.

Heavier locomotives and larger cars are more expensive to maintain, so with the advent of heavier power and other rolling stock, higher maintenance costs are to be expected, not only of locomotives but of cars. Improved transportation efficiency is therefore purchased at an increase in maintenance of equipment costs.

An almost fixed relationship exists between weight of locomotives and tractive force, so the latter unit then can be taken as a measure of the size or weight of loco-

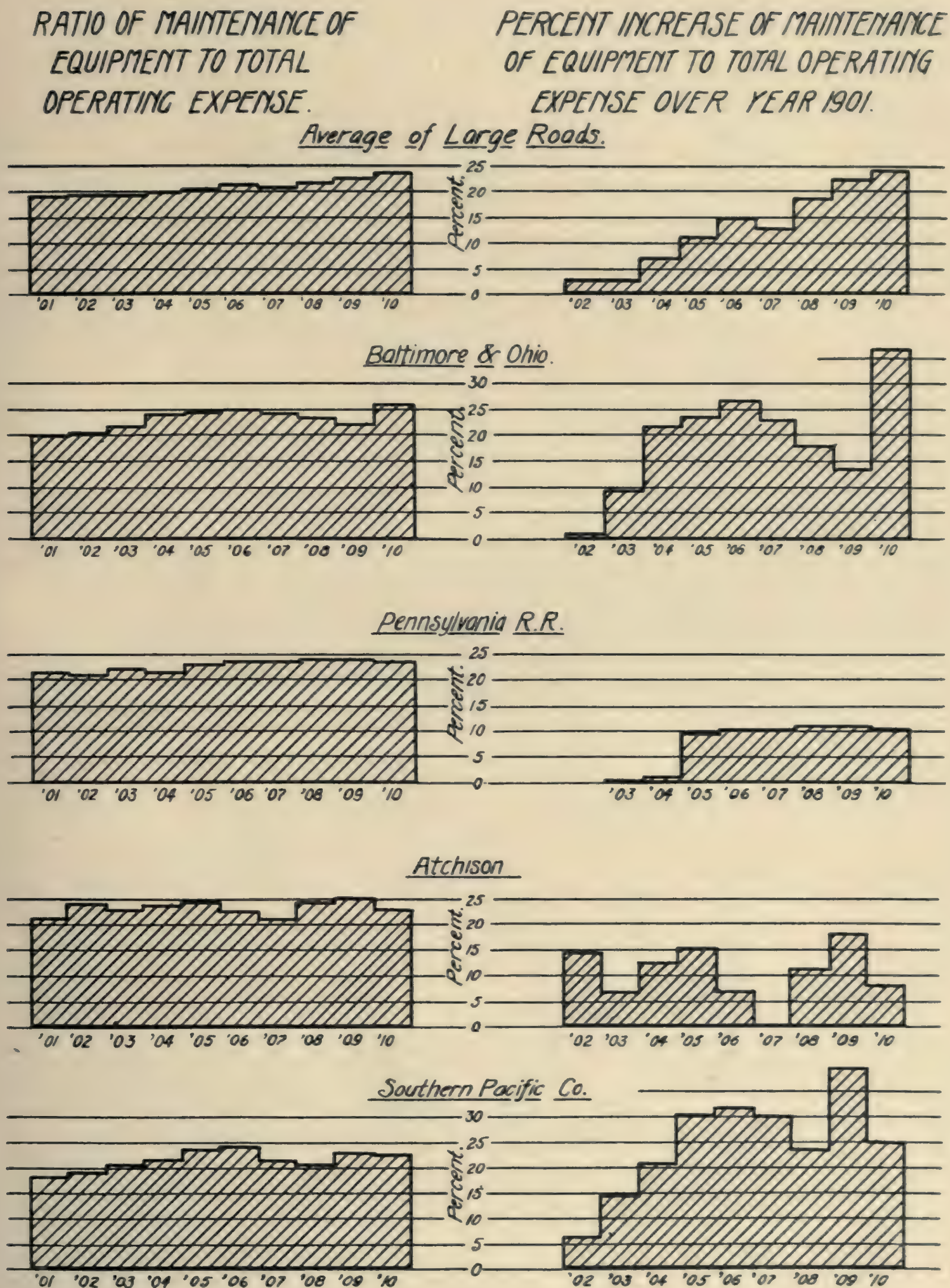

RATIO OF MAINTENANCE OF EQUIPMENT TO TOTAL OPERATING EXPENSE.
PERCENT INCREASE OF MAINTENANCE OF EQUIPMENT TO TOTAL OPERATING EXPENSE OVER YEAR 1901.
Average of Large Roads.
Baltimore & Ohio.
Pennsylvania R.R.
Atchison
Southern Pacific Co.
Percent.
'01 '02 '03 '04 '05 '06 '07 '08 '09 '10
0 5 10 15 20 25 30

FIG. 12

motives. The average tractive force of locomotives from 1902 to 1910 with the per cent. increase compared with the year 1902 is shown in Fig. 13, and accompanying table.

TRACTIVE FORCE

Year	Average Per Locomotive, Pounds	Per Cent. Increase Compared with 1902
1902	20,480	00.0%
1903	21,780	6.3
1904	22,800	11.3
1905	23,430	14.4
1906	24,740	20.0
1907	25,640	25.2
1908	26,356	28.6
1909	26,634	30.0
1910	27,282	33.2

There is also a remarkable similarity in the increase of capacity of freight cars and tractive force of locomotives for the period between 1902 and 1910. During this time the capacity of freight cars has increased 28.6 per cent. and the tractive force of locomotives 33.2 per cent. Cars and locomotives have steadily grown larger in approximately the same ratio from year to year.

The average capacity of freight cars from 1902 to 1910, with the per cent. increase compared with the year 1902, is shown in Fig. 14, and accompanying table.

CAPACITY OF FREIGHT CARS

Year	Average Per Car, Tons	Per Cent. Increase Compared with 1902
1902	28	00.0%
1903	29	3.6
1904	30	7.1
1905	31	10.7
1906	32	14.3
1907	34	21.4
1908	35	25.0
1909	35	25.0
1910	36	28.6

The comparison of locomotive tractive force and freight car capacity with maintenance of equipment to total operating expense for the period between 1901 and 1910 (Figs. 12, 13 and 14) establishes a close relationship between maintenance costs and size of equipment. Through the medium of larger equipment, lower costs

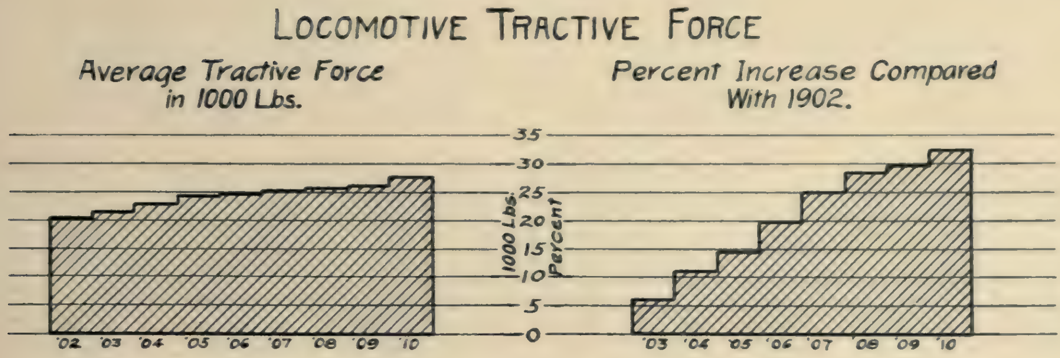


FIG. 13

of conducting transportation are secured, entailing, however, increased equipment charges in proportion to the size of equipment.

Maintenance charges for large equipment are greater per unit on account of increased size of locomotives and cars, more extensive shops and terminals, heavier machinery and modern facilities for handling and repairing, increased wear and tear on equipment from heavier trains and the various other items coincident with operation of heavier power.

In the maintenance of equipment, the topography of the country also governs to a large extent. In a comparatively level country, locomotives are of medium size with large driving wheels and are able to run at fairly high speeds, while locomotives in a mountainous district are much heavier, are equipped with small driving wheels and must run at slow speeds, thus increasing the maintenance of equipment costs. The service conditions are more severe upon the locomotives and the cost of locomotive repairs as well as freight and passenger car repairs are correspondingly higher.

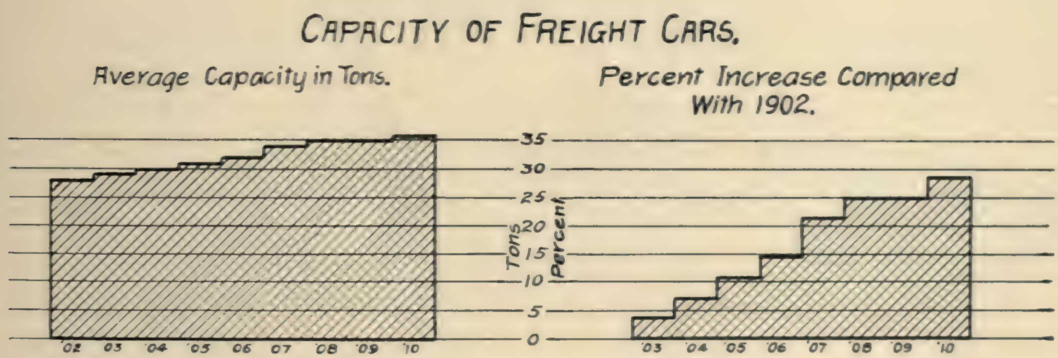


FIG. 14

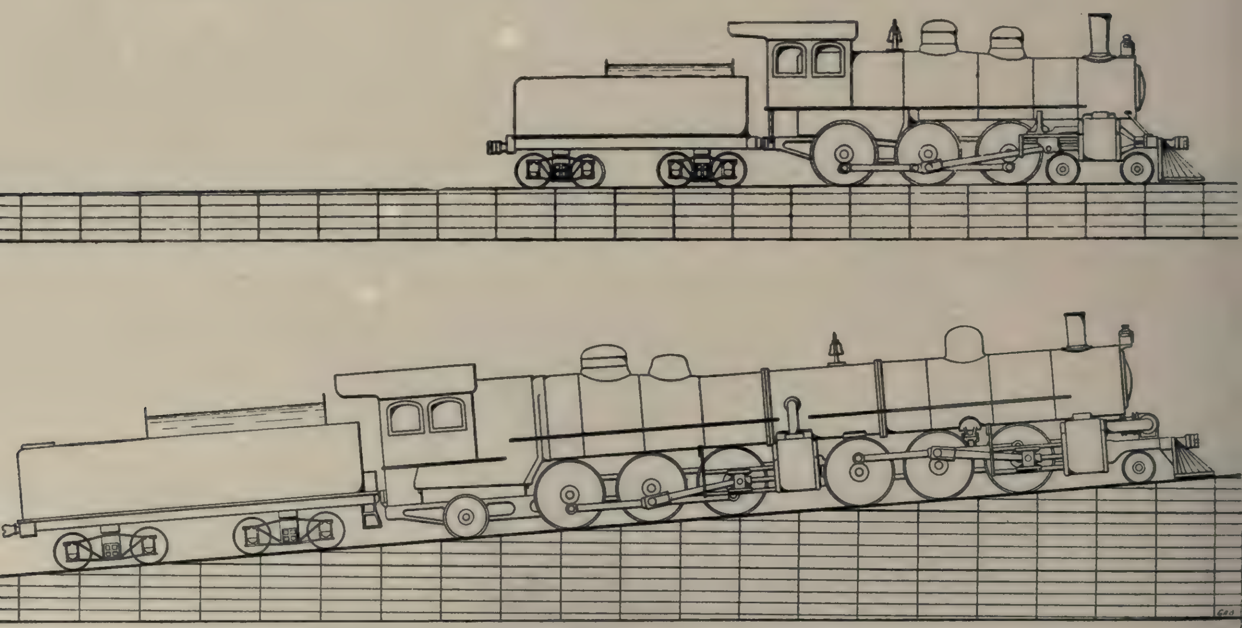
A graphical representation is given herewith (Fig. 15), showing the difference in size of locomotives necessary to haul the same train on level track and on a heavy grade.

The cost of locomotive maintenance and operation is from 50% to 60% higher on the territory with heavy grades than where grades are a negligible quantity, even though the capacity of the locomotives on the grades may be much greater.

The mileage made by heavy mountain locomotives is manifestly lower than locomotives running in a prairie country. The large consolidated and Mikado freight locomotives in mountain service average about 2,000 miles per month as compared with 3,000 or 3,500 miles per month made by freight locomotives in a prairie country. It is therefore decidedly unfair to compare locomotive maintenance costs on a mileage basis only.

To contribute a graphical representation of the difference in the topography of level and mountainous districts, portions of profiles are given (Fig. 16). Under the profile illustration of the level country is shown the density of traffic, with the cost of locomotive repairs and fuel per 1,000 gross ton miles. Beneath the profile illustrating the mountainous section is shown the same information, also the cost of repairs and fuel for a twelve months period.

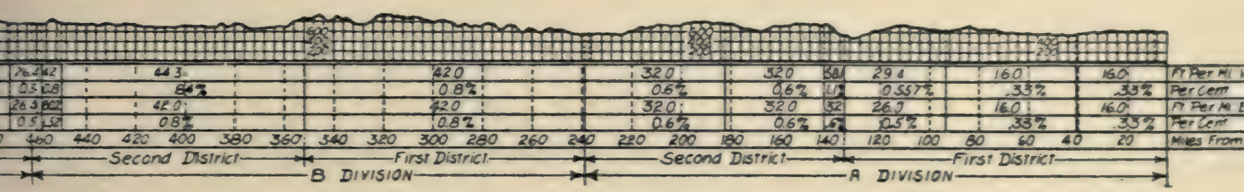
On the level country the density of freight traffic was 70.1% greater than on the mountainous country. From the following statement, tabulated from official data, it is evident that locomotive expenses, repairs, and fuel are 59.1% greater in the mountainous country than in the level country.



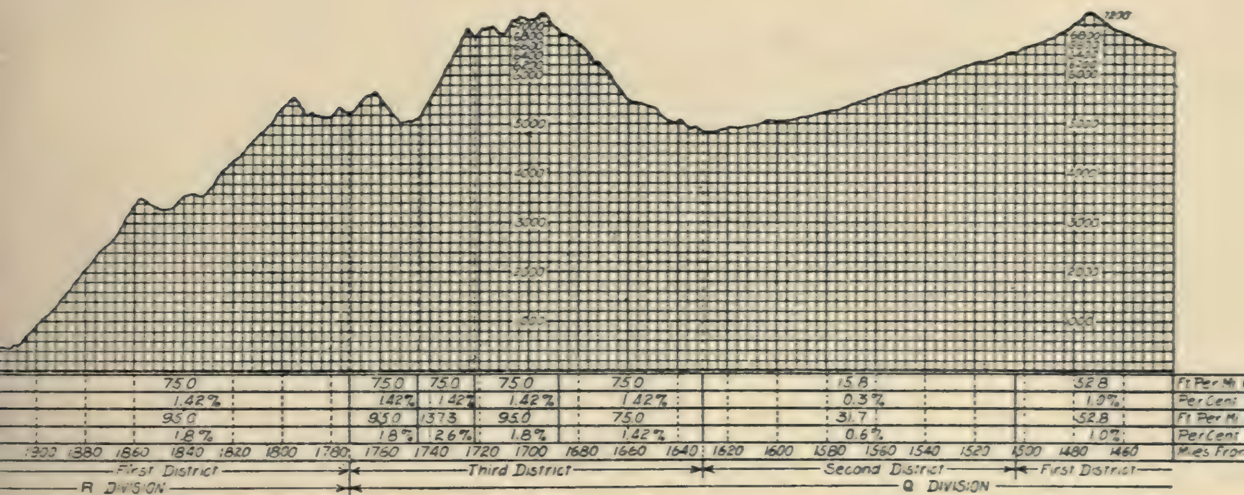
GRAPHICAL REPRESENTATION OF DIFFERENCE IN SIZE OF LOCOMOTIVES HAULING SAME TRAIN ON LEVEL AND ON GRADE

FIG. 15

Cost of Freight Locomotive Repairs and Fuel in Level and Mountainous Country for 12 Months Period



	Level Country
1000 Gross Ton Miles	5,300,827
Density of Traffic, per mile, 1000 G. T. M.	6,884
Total Cost of Locomotive Repairs and Fuel	$1,396,729
Cost of Locomotive Repairs and Fuel per 1000 G. T. M.	0.264



	Mountainous Country
1000 Gross Ton Miles	4,049,015
Density of Traffic, per Road Mile, 1000 G. T. M.	4,049
Total Cost of Locomotive Repairs and Fuel	$1,699,182
Cost of Locomotive Repairs and Fuel per 1000 G. T. M.	0.420
At Traffic Density in level country, increased cost of Repairs and Fuel would be	$1,190,000

Fig. 16

Cost of Locomotive Repairs and Fuel in Level and Mountainous Country.

Main Line Freight—12 Months Period.

	Level Country	Mountainous Country
Total 1,000 Gross Ton Miles..............	5,300,827	4,049,015
Road Mileage..........................	770	1,000
Density of Traffic, per Road Mile 1000 Gross Ton Miles..........................	6,884	4,049
Total Cost of Repairs..................	$ 599,689	$ 647,886
Total Cost of Fuel......................	797,040	1,051,296
Total	$1,396,729	$1,699,182
Cost of Repairs, per Road Mile............	$ 799	$ 648
Cost of Fuel, per Road Mile...............	1,035	1,051
Total	$ 1,814	$ 1,699
Cost of Repairs and Fuel, 1000 G. T. M......	$ 264	$ 420
Increased Cost of Repairs and Fuel on 1000 G. T. M. basis of mountainous over level country		$ 631,646
Per Cent. Increase per 1000 G. T. M......	70.1%	
Cost per Road Mile at Traffic Density of Level country		$ 2,889
Increased Cost per Road Mile		$ 1,190
If business were increased 70.1% on the mountainous country, so that the density of traffic should be as great as on the level country, the increased cost for locomotive repairs and fuel would be 1,190 x 1,000 or		$1,190,000

The expenditure for Maintenance of Equipment on the Burlington in 1910 amounted to $1,669 per mile of road as compared with $921 in 1902; however, in the meantime, the tonnage handled per mile of track nearly doubled. During the same period, the weight of locomotives increased 40 per cent. and the average capacity of freight cars increased from 24.7 tons to 33.6 tons or 36 per cent.

The great extremes that exist in Maintenance of Equipment expenditures (and undoubtedly each is justified in the expenditure) are shown on the Minneapolis & St. Louis with a ten-year average of $500 per mile of road as compared with the Philadelphia & Reading, which expended $5,932 per mile of road during the same period. To look at these figures alone one would say that the Philadelphia & Read-

ing spent twelve times as much money annually as was necessary for Maintenance of Equipment, which inference is of course absurd.

Again the nature and character of traffic has much to do with Maintenance of Equipment costs. The Burlington, for example, has its so-called "stock rush," where a great volume of stock must be transported at high speed. Often consignments of 20 or 25 cars are received that cannot wait for other cars to make a full train, which results in high costs. On the other hand about two-thirds of the tonnage of the Lackawanna is made up from the products of mines, which can be hauled in large capacity cars at low speeds, resulting in remarkably low costs.

The Southern Pacific presents another example of the same nature. A great deal of their business consists of fruit from Southern California, which must be handled when the consignments are iced and ready to go and must run at high speed. This causes a heavy traffic east-bound with a correspondingly light movement west. The Great Northern, however, has a steady slow freight business, carrying wheat west and lumber east-bound, thereby being able to make a much better showing than the Southern Pacific in equipment maintenance costs.

It is therefore evident that the employment of the unit "per mile" of road for comparing Maintenance of Equipment performance without special reference to operating conditions, and character and volume of business, is meaningless and of doubtful value.

The same thing may be said of the comparisons of total Maintenance of Equipment per locomotive mile, inasmuch as increased tonnage per engine mile may decrease the cost of operation per ton mile, but will increase the maintenance cost per locomotive mile so that each of the several divisions must be subjected to a separate analysis.

The gross tons hauled one mile is a fair and equable unit to use as a basis in computing maintenance costs. Although the gross ton mile is made use of on some railroads, the published statements and the Interstate Commerce Commission reports do not show this very important figure, nor do railroads generally use it for a basis of computation. The figure used is the revenue ton mile, which may be the all-important figure when considered financially, but it is not the basis which should be used when considering maintenance of equipment costs.

Many roads, necessarily, haul company material long distances. Locomotive fuel, for example, on the Southern Pacific amounts to 8,000 net tons per day and is carried in many instances 300 or 400 miles with a corresponding empty car mileage back. The Pennsylvania mines its coal on the line of road and hauls it but a few miles. Iron products of all kinds, rails, boiler steel, car wheels, axles, shop machinery and tools, all go to make a heavy tonnage for long distances on western roads which constitute non-revenue freight and consequently do not appear to the credit of the locomotives which do the work of hauling. It is thus manifestly unfair to compare maintenance costs of western roads with eastern roads on a revenue ton mile basis, but it would be reasonably fair if the gross ton miles were used.

Operating conditions on the railroads east of Chicago are along fixed and tried lines, while the west is in a more or less new and unsettled condition. Labor in the west is scarce and generally of poor quality. It is therefore necessary to pay higher wages in order to attract the better class of labor from the east.

As the labor charge constitutes more than one-half the maintenance costs of equipment, the higher wages paid on western roads will be reflected directly in the total when comparisons are made with eastern roads. Metal workers, wood workers, and miscellaneous shop labor include most of the employees in the locomotive and car shops and fairly represent the general labor situation.

The total figures taken from the Interstate Commerce Commission records, separated into eastern and western roads, are shown in chart form in Fig. 17, with actual figures as follows:

WAGES PER HOURS.

	Eastern Roads	Western Roads	Per Cent. Increase Western Over Eastern Roads
Metal Workers	$0.265	$0.327	23%
Wood Workers	.226	.253	12
Miscl. Shop Labor	.197	.215	9

This marked increase of 23 per cent. in wages paid metal workers on western roads is a most important item and should be given due weight when comparisons are made between eastern and western roads.

It is obvious that any comparison of maintenance of equipment expenses between any two roads must necessarily include a comprehensive analysis of all influencing factors. It is also apparent that no single comparative unit can be established that will reflect true conditions of maintenance of equipment expense as a

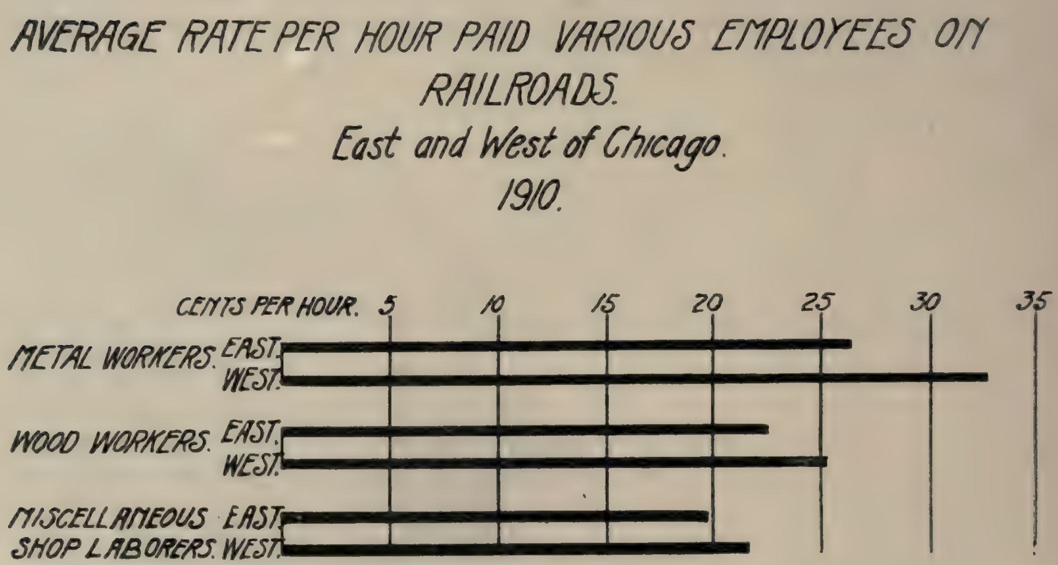


FIG. 17

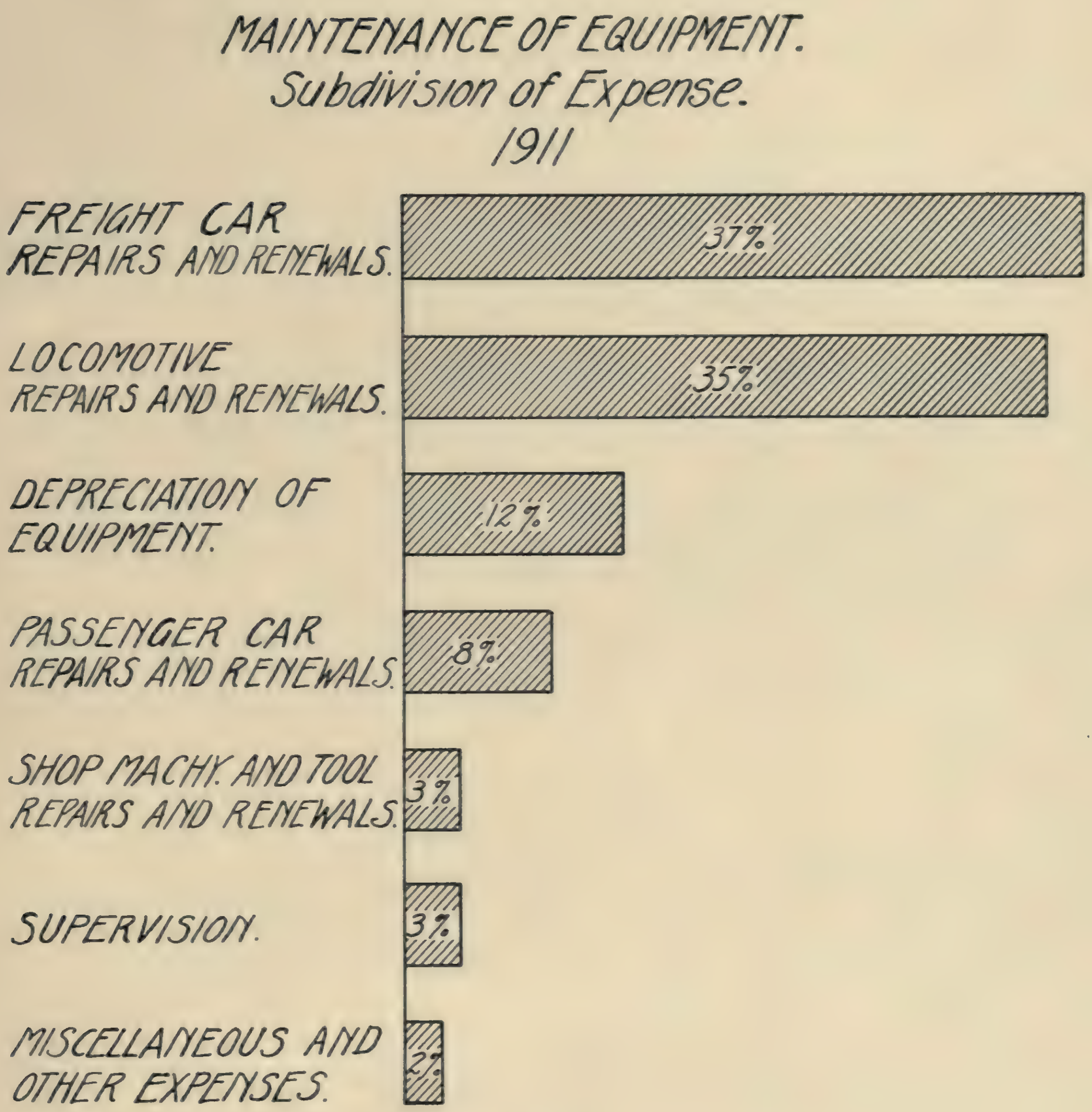

MAINTENANCE OF EQUIPMENT.
Subdivision of Expense.
1911
FREIGHT CAR REPAIRS AND RENEWALS.
37%
LOCOMOTIVE REPAIRS AND RENEWALS.
35%
DEPRECIATION OF EQUIPMENT.
12%
PASSENGER CAR REPAIRS AND RENEWALS.
8%
SHOP MACHY. AND TOOL REPAIRS AND RENEWALS.
3%
SUPERVISION.
3%
MISCELLANEOUS AND OTHER EXPENSES.
2%

FIG. 18

whole, since any change in the size and design of locomotive and cars may exert such influence on the maintenance costs as to destroy the comparative value on the same road for different periods.

The total expenditures for maintenance of equipment on the railroads in the United States during the fiscal year 1911 were subdivided as follows (Fig. 18):

Freight Cars (Repairs and Renewals)	37%
Locomotives (Repairs and Renewals)	35%
Depreciation of Equipment	12%
Passenger Cars (Repairs and Renewals)	8%
Shop Machinery and Tools	3%
Supervision	3%
Miscellaneous and other Expenses	2%

While the charges for depreciation of equipment constitute 12% of the total charges for maintenance of equipment, these studies of maintenance costs have been confined entirely to the expenditures for repairs and renewals, as they permit of more accurate comparisons.

Each individual item of maintenance of equipment expenses must be subjected to a separate analysis and an individual comparative unit established, if necessary, to enable true conditions to be reflected.

Freight Car Maintenance

CHAPTER IV.

The repairs and renewals of freight cars, usually regarded by railroad officials as an item of secondary importance in the maintenance of equipment expenditures, is the largest single item of these expenses.

In 1911 these expenditures consumed 37 per cent. of the total maintenance of equipment and 8.4 per cent. of the total operating expenses of all the railroads in the United States, as compared with the repairs and renewals of locomotives which consumed 35 per cent. of the maintenance of equipment and 8.0 per cent. of the total operating expenses.

The percentage of operating expenses devoted to the maintenance of freight cars fluctuated on the individual railroads during 1911 from 3.8 per cent. on the New Haven to 14.9 per cent. on the Reading. There were thirteen railroads, during this period where this percentage was in excess of 10 per cent., while there were only eight railroads where the maintenance of locomotives was above that figure, which further emphasizes the greater importance of freight car maintenance.

Continuing the comparison further, it is found that freight car maintenance amounted to 180 per cent. of the locomotive maintenance on the Pittsburg & Lake Erie; 150 per cent. on the Chesapeake & Ohio; 147 per cent. on the L. S & M. S.; 142 per cent. on the Michigan Central; 133 per cent. on the Burlington. In contrast with this, it amounted to but 65 per cent. of the maintenance of locomotives on the New Haven, 61 per cent. on the Union Pacific; 54 per cent. on the Santa Fe and 43 per cent. on the Missouri Pacific.

From this study of the maintenance costs on the various railroads, it is very evident that the maintenance of freight cars is entitled to the same consideration as that usually accorded to the maintenance of power units. That repairs and renewals of freight cars is usually relegated to a relatively unimportant place in the maintenance of equipment expenses, is evident from the absence of comparative units, permitting these costs to be checked up in a regular manner as in the case of maintenance of locomotives.

With these costs averaging 8.5 per cent. of the total operating expenses of all of the railroads in the country, and on individual railroads reaching as high as 14.9 per cent., it appears that these expenditures are of sufficient consequence to be given a detailed study. To permit performance records to be checked up for various periods, a proper comparative unit should be determined in order that these comparisons can be of value.

The common method of comparisons of these maintenance costs is the average annual expenditure per freight car owned, which figures are always given considerable prominence in the annual reports of railroad presidents and in railroad journals

analysing maintenance expenses. Accompanying chart, Fig. 19, is shown herewith illustrating the cost per freight car owned on a majority of the leading railroads for the year 1911, as follows:

MAINTENANCE OF FREIGHT CARS—PER FREIGHT CAR OWNED

1911

N. Y. N. H & H	$ 40.34	C. & O.	$ 65.64
B. & M.	65.84	N. & W.	63.84
N. Y. Central	111.39	Atl. Coast Line	63.64
Penn. R. R.	69.42	Seab. Air Line	60.26
D. L. & W.	57.66	Southern	69.29
L. V.	53.77	Ill. Central	83.45
D. & H.	59.75	L. & N.	74.96
C. R. R. of N. J.	54.48	Nash. C. & St. L.	74.26
P. & R.	96.87	Mob. & Ohio	71.43
Erie	60.11	C. & A.	71.13
B. & O.	61.11	C. B. & Q.	93.00
L. E. & W.	125.65	C. R. I. & P.	76.96
P. & L. E.	41.41	Frisco	62.19
Penn. Co.	64.46	C. M. & St. P.	80.54
P. C. C. & St. L.	114.82	Union Pacific	108.21
L. S. & M. S.	71.13	Colo. & Sou.	69.08
Mich. Central	88.80	D. & R. G.	70.98
Pere Marq.	56.32	Santa Fe	78.05
C. C. C. & St. L.	100.20	Sou. Pac.	112.31
Vandalia	83.33	Nor. Pac.	55.01

From this table it is noted that the cost per freight car owned varies from $40.34 on the New Haven to $125.65 on the L. E. & W. If the cost per car owned is the proper comparative unit, to be used, then the maintenance of freight cars on the L. E. & W. during 1911 was more than three times the necessary expenditure.

Again taking two trunk lines operating in the same general territory, the Santa Fe with maintenance of $78.75 per freight car owned and the Northern Pacific with $55.01 per car owned. If the cost per car is the proper unit, then the Santa Fe should be able to effect a reduction of 30 per cent. in freight car maintenance for the year 1911, with Northern Pacific figures used as a standard. Also the Santa Fe should reduce their freight car maintenance 48 per cent. if the performance of the New Haven is taken as a standard.

It is very evident there are several important factors entering into the maintenance of freight cars, which will modify the value of the unit "freight car owned," i. e., the total number of cars owned, the average capacity of the cars and the average miles run.

Two railroads handling the same tonnage during the same period of time, may with reason be expected to have equal expenditures for maintenance of freight cars.

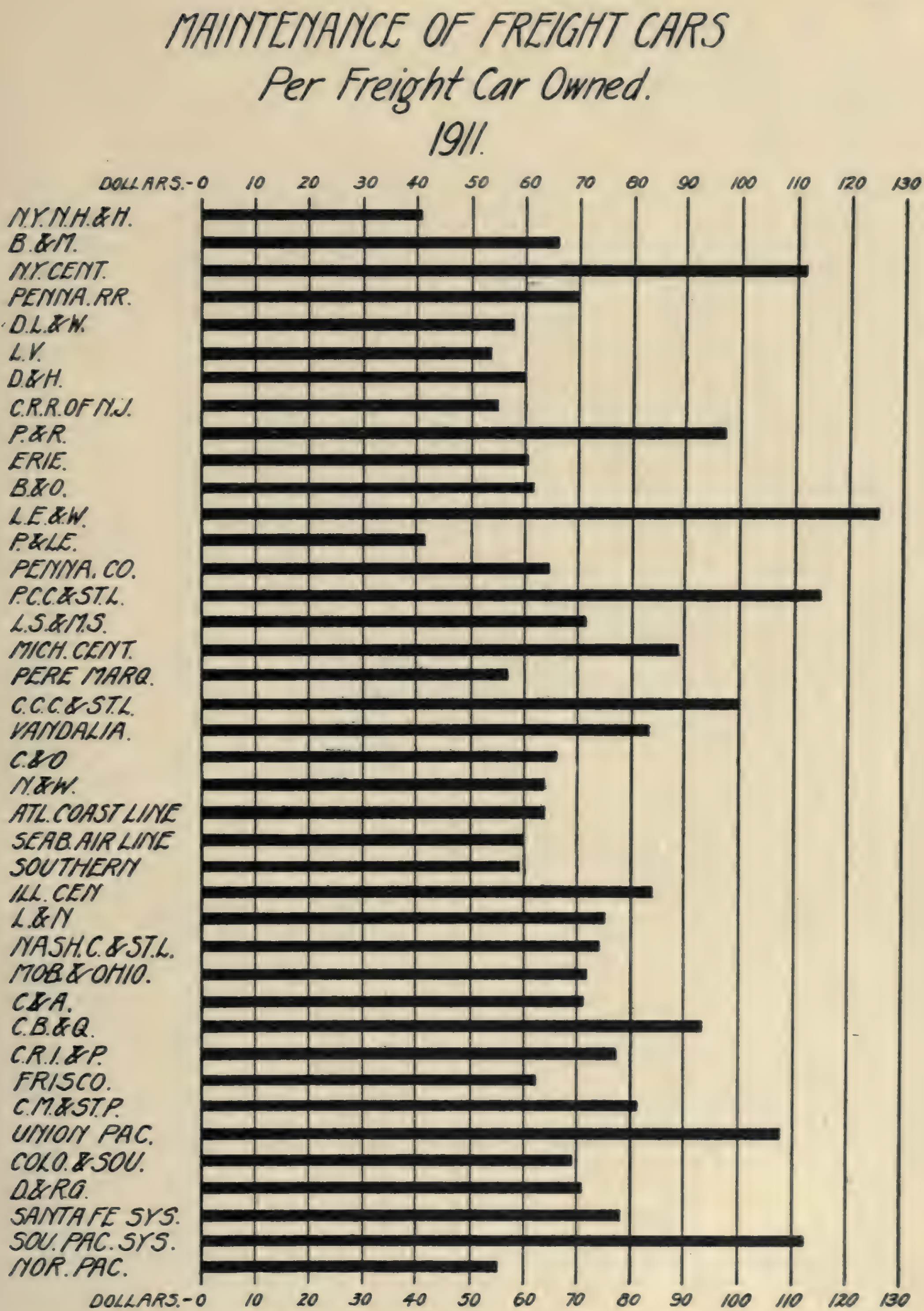

MAINTENANCE OF FREIGHT CARS
Per Freight Car Owned.
1911.
DOLLARS.- 0 10 20 30 40 50 60 70 80 90 100 110 120 130
N.Y.N.H.&H.
B.&M.
N.Y.CENT.
PENNA.RR.
D.L.&W.
L.V.
D.&H.
C.R.R.OF N.J.
P.&R.
ERIE.
B.&O.
L.E.&W.
P.&L.E.
PENNA. CO.
P.C.C.&ST.L.
L.S.&M.S.
MICH.CENT.
PERE MARQ.
C.C.C.&ST.L.
VANDALIA.
C.&O
N.&W.
ATL.COAST LINE
SEAB.AIR LINE
SOUTHERN
ILL.CEN
L.&N
NASH.C.&ST.L.
MOB.&OHIO.
C.&A.
C.B.&Q.
C.R.I.&P.
FRISCO.
C.M.&ST.P.
UNION PAC.
COLO.&SOU.
D.&R.G.
SANTA FE SYS.
SOU.PAC.SYS.
NOR.PAC.
DOLLARS.- 0 10 20 30 40 50 60 70 80 90 100 110 120 130

FIG. 19

They may, however, due to different policies in the purchasing of equipment, estimating of equipment requirements, unexpected change in character of volume of traffic, have considerable variation in the number of freight cars. It follows, therefore, that the railroad with the greater number of cars will have the lesser cost per car, which, if this standard be correct, is indicative of higher efficiency in management.

For example; the freight traffic density (100,000 revenue ton miles per mile of track) in 1911 on the L. E. & W. was 7.32 and on the New Haven 7.45, which indicates the volume of freight business on these two roads to be similar. Further investigation shows that the New Haven owned 38,783 cars with 3,079 miles of total track (exclusive of all yards and sidings), and the L. E. & W. owned 3,840 cars with 895 miles of total track. From these figures it is apparent that the L. E. & W. with 29 per cent. of the mileage of the New Haven and a similar traffic density owns less than 10 per cent. of the number of freight cars possessed by the New Haven.

Again, one railroad may have a few cars and a high average mileage, thus handling the same volume of business as another railroad having a larger number of cars and a small average mileage.

AVERAGE CAPACITY OF FREIGHT CARS

1911

	Tons		Tons
N. Y. N. H. & H.	32.30	C. & O.	43.40
B. & M.	29.70	N. & W.	44.35
N. Y. Central	36.60	Atl. Coast Line	28.72
Penn. R. R.	44.90	Seab. Air Line	33.95
D. L. & W.	32.90	Southern	35.10
Leh. Valley	36.40	Ill. Central	38.40
D. & H.	36.78	L. & N.	35.20
C. R. R. of N. J.	37.22	Nash. C. & St. L.	31.02
P. & R.	35.20	Mob. & Ohio	34.14
Erie	37.50	C. & A.	40.00
B. & O.	39.20	C. B. & Q.	36.30
L. E. & W.	32.04	C. R. I & P.	35.40
P. & L. E.	41.18	Frisco	37.50
Penn. Co.	43.40	C. M. & St. P.	31.80
P. C. C. & St. L.	45.30	Union Pac.	39.10
L. S. & M. S.	41.20	Colo. & Sou.	33.96
Mich. Central	35.35	D. & R. G.	35.23
Pere Marq.	33.49	Santa Fe Sys.	32.10
C. C. C. & St. L.	35.94	Sou. Pac. Sys.	40.40
Vandalia	43.44	Nor. Pac.	35.60

Continuing the study between the railroads that have been previously mentioned, we find that the average mileage per freight car in 1911 on the L. E. & W. was 13,547 miles and on the New Haven 5,530 miles. If the freight cars on the New

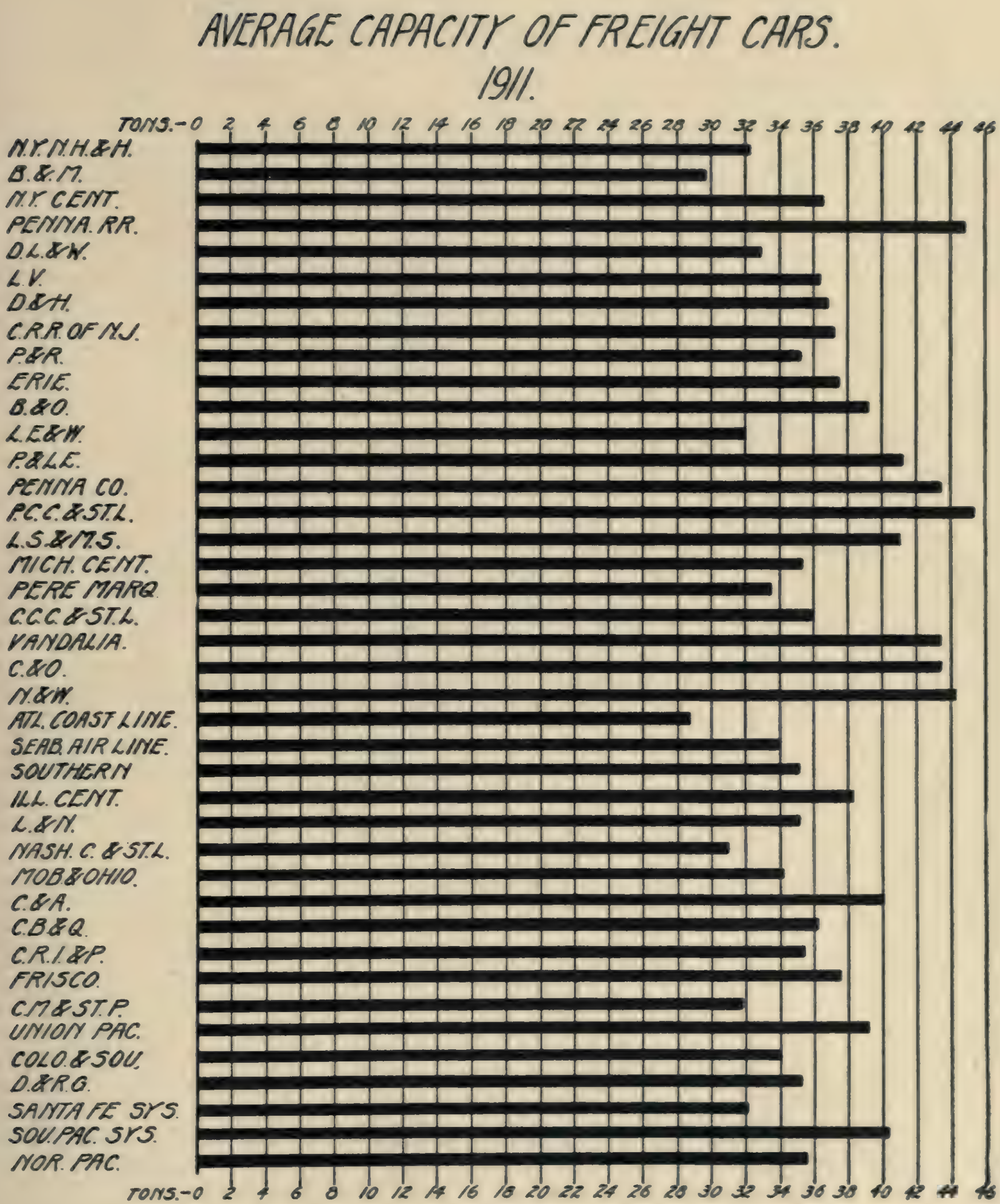

AVERAGE CAPACITY OF FREIGHT CARS.
1911.
TONS.-0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46
N.Y.N.H.&H.
B.&M.
N.Y. CENT.
PENNA. RR.
D.L.&W.
L.V.
D&H.
C.R.R. OF N.J.
P&R.
ERIE.
B.&O.
L.E.&W.
P.&L.E.
PENNA CO.
P.C.C.&ST.L.
L.S.&M.S.
MICH. CENT.
PERE MARQ.
C.C.C.&ST.L.
VANDALIA.
C.&O.
N.&W.
ATL. COAST LINE.
SEAB. AIR LINE.
SOUTHERN
ILL. CENT.
L.&N.
NASH. C.&ST.L.
MOB.&OHIO.
C.&A.
C.B.&Q.
C.R.I.&P.
FRISCO.
C.M.&ST.P.
UNION PAC.
COLO.&SOU.
D.&R.G.
SANTA FE SYS.
SOU. PAC. SYS.
NOR. PAC.
TONS.-0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46

Fig. 20

Haven had made the same average mileage as those on the L. E. & W., the number of cars required for the New Haven would have been so reduced as to make the maintenance per freight car for 1911 equal to $99.00 in place of $40.34, which figures would indicate an entirely different condition with reference to efficiency in freight car maintenance than that inferred in the first paragraph.

From this it would appear that the remarkably low cost on the New Haven as compared with the high cost on the L. E. & W., in place of reflecting economy in one case and extravagance in the other, is only conclusive evidence that the maintenance "per freight car owned" is useless as a comparative unit.

The average capacity of freight cars on the various railroads must be taken into consideration in any analysis as larger cars carrying greater weight must necessarily require higher expenditure for maintenance on a "per car owned" basis.

Miles Per Freight Car Owned

1911

	Miles		Miles
N. Y. N. H & H	5,520	C. & O	7,750
B. & M	8,599	N. & W	9,517
N. Y. Central	11,913	Atl. Coast Line	8,340
Penn. R. R	7,856	Seab. Air Line	8,991
D. L. & W	8,638	Southern	7,948
Leh. Valley	7,323	Ill. Central	9,021
D. & H	7,710	L. & N	8,861
C. R. R. of N. J	6,173	Nash. C. & St. L	8,412
P. & R	7,192	Mob. & Ohio	10,820
Erie	8,554	C. & A	9,817
B. & O	8,869	C. B. & Q	11,765
L. E. & W	13,547	C. R. I. & P	10,860
P. & L. E	4,009	Frisco	7,665
Penna. Co	7,016	C. M. & St. P	11,428
P. C. C. & St. L	12,650	Union Pac	19,521
L. S. & M. S	8,375	Colo. & Sou	6,125
Mich. Central	11,402	D. & R. G	5,765
Pere Marq	8,029	Santa Fe Sys	12,858
C. C. C. & St. L	11,715	Sou. Pac. Sys	11,859
Vandalia	9,119	Nor. Pac	7,911

While the average freight car capacity of 32.3 tons on the New Haven compares favorably with 32.04 tons on the L. E. & W., this similarity is not in evidence when all the leading railroads are considered.

A chart, Fig. 20, and accompanying data show the average capacity of freight cars on 40 roads for the year 1911. The capacity varies from 28.7 tons on the Atlantic Coast Line to 45.3 tons on the P. C. C. & St. L., a difference of approximately 58 per cent.

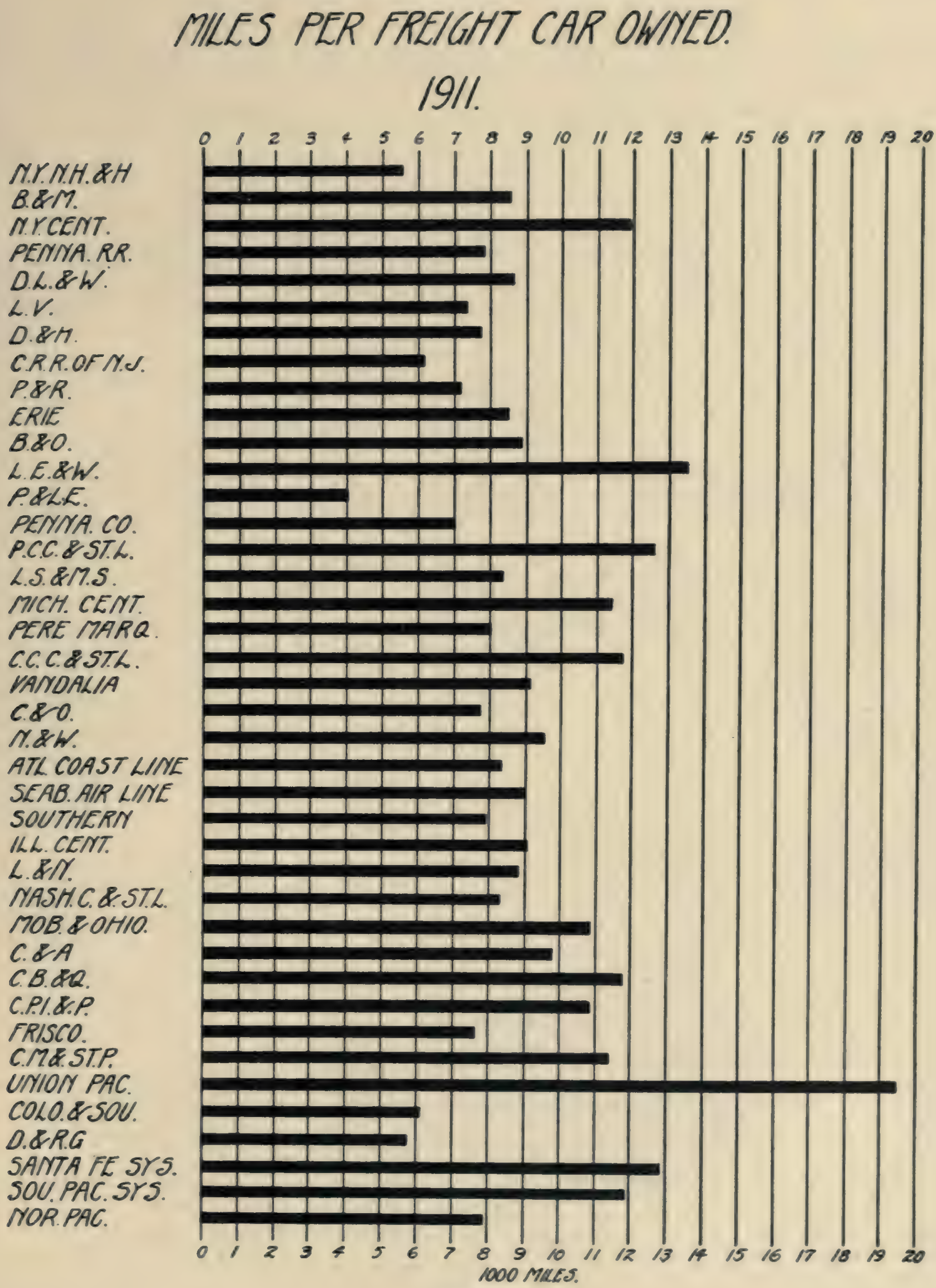

MILES PER FREIGHT CAR OWNED.
1911.
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
N.Y.N.H.&H
B.&M.
N.Y.CENT.
PENNA. RR.
D.L.&W.
L.V.
D.&H.
C.R.R.OF N.J.
P.&R.
ERIE
B.&O.
L.E.&W.
P.&L.E.
PENNA. CO.
P.C.C.&ST.L.
L.S.&M.S.
MICH. CENT.
PERE MARQ.
C.C.C.&ST.L.
VANDALIA
C.&O.
N.&W.
ATL. COAST LINE
SEAB. AIR LINE
SOUTHERN
ILL. CENT.
L.&N.
NASH.C.&ST.L.
MOB.&OHIO.
C.&A
C.B.&Q.
C.R.I.&P.
FRISCO.
C.M.&ST.P.
UNION PAC.
COLO.&SOU.
D.&R.G
SANTA FE SYS.
SOU. PAC. SYS.
NOR. PAC.
1000 MILES.

FIG. 21

The yearly mileage per freight car owned is presented in Fig. 21, and shows a variation from 4,009 miles on the P. & L. E. to 19,521 miles on the Union Pacific—a difference of 388 per cent.

These charts serve to illustrate that the maintenance costs "per car owned" are useless for comparative purposes. The variation in the amount of equipment owned will also render comparisons on this basis valueless either between roads or for different periods on the same road.

In order to permit a comparison of the amount of freight car equipment among these various railroads, the number of freight cars owned per mile of total track (exclusive of yards and sidings), is shown and illustrated in Fig. 22. This number varies from 3.8 cars per mile on the Union Pacific to 47.95 cars on the Pittsburg & Lake Erie.

Freight Cars Owned Per Mile of Track

1911

	Cars		Cars
N. Y. N. H. & H.	12.60	C. & O.	16.67
B. & M.	9.21	N. & W.	17.38
N. Y. Central	11.96	Atl. Coast Line	5.49
Penn. R. R.	23.33	Seab. Air Line	4.90
D. L. & W.	20.04	Southern	7.03
Leh. Valley	20.84	Ill. Central	11.16
D. & H.	16.80	L. & N.	9.36
C. R. R. of N. J.	23.70	Nash. C. & St. L.	8.32
P. & R.	26.16	Mob. & Ohio	9.53
Erie	16.37	C. & A.	9.85
B. & O.	15.57	C. B. & Q.	5.26
L. E. & W.	4.29	C. R. I & P.	5.24
P. & L. E.	47.95	Frisco	6.51
Penn. Co.	24.58	C. M. & St. P.	5.48
P. C. C. & St. L.	11.63	Union Pac.	3.80
L. S. & M. S.	18.23	Colo. & Sou.	6.88
Mich. Central	10.25	D. & R. G.	6.78
Pere Marq.	7.22	Santa Fe Sys.	4.96
C. C. C. & St. L.	10.26	Sou. Pac. Sys.	4.60
Vandalia	10.07	Nor. Pac.	6.28

The amount of equipment per mile of track is of no value without data reflecting the value of business and for this purpose the following comparative figures, i. e., 100,000 revenue ton miles per mile of total track is submitted with illustration Fig. 23. This table shows a fluctuation in freight traffic density between 3.83 on the Atlantic Coast Line and 39.1 on the Pittsburg & Lake Erie.

The value of the unit "per mile of total track" (exclusive of yards and sidings), employed to designate the traffic density of any road as compared with the unit


NUMBER OF FREIGHT CARS OWNED
Per Mile of Total Track.
1911.
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48
N.Y.N.H.&H.
B.&M.
N.Y. CENT.
PENNA. R.R.
D.L.&W.
L.V.
D.&H
C.R.R. OF N.J.
P.&R.
ERIE
B.&O.
L.E.&W.
P.&L.E.
PENNA. CO
P.C.C.&ST.L.
L.S.&M.S.
MICH. CENT.
PERE MARQ.
C.C.C.&ST.L.
VANDALIA
C.&O.
N.&W.
ATL. COAST LINE
SEAB. AIR LINE
SOUTHERN
ILL. CENT.
L.&N.
NASH. C. & ST.L.
MOB. & OHIO.
C.&A.
C.B.&Q.
C.R.I.&P.
FRISCO
C.M.&ST.P.
UNION PAC.
COLO. & SOU.
D.&R.G.
SANTA FE SYS.
SOU. PAC. SYS.
NOR. PAC.

FIG. 22

"per mile of road" employed in Chapter I, can be better appreciated by a study of the two charts illustrating the volume of business by means of the two units.

The one "per mile of road" using the geographical mileage, takes no account of the additional trackage of a two, three or four track road, while the other "per mile

Freight Traffic Density—100,000 Revenue Ton Miles per Mile of Track

1911

N. Y. N. H. & H.	7.45	C. & O.	23.65
B. & M.	8.23	N. & W.	28.38
N. Y. Central	15.90	Atl. Coast Line	3.83
Penna. R. R.	31.12	Seab. Air Line	4.18
D. L. & W.	25.27	Southern	5.43
L. V.	22.98	Ill. Central	12.47
D. & H.	20.75	L. & N.	10.62
C. R. R. of N. J.	23.70	Nash. C. & St. L.	6.83
Phila. & Read.	28.51	Mob. & Ohio	11.96
Erie	20.01	C. & A.	12.48
B. & O.	20.18	C. B. & Q.	7.25
L. E. & W.	7.32	C. R. I. & P.	5.73
P. & L. E.	39.10	Frisco	5.41
Penna. Co.	11.14	C. M. & St. P.	6.48
P. C. C. & St. L.	19.28	Union Pac.	8.85
L. S. & M. S.	21.15	Colo. & Sou.	6.35
Mich. Central	12.74	D. & R. G.	5.14
Pere Marq.	7.27	Santa Fe Sys.	6.55
C. C. C. & St. L.	15.18	Sou. Pac. Sys.	6.40
Vandalia	12.42	Nor. Pac.	6.89

of track" considers all trackage except that employed for yards and sidings. The value of the latter unit is readily apparent.

In an endeavor to take into consideration the volume of business, another unit has been used to a limited extent in comparing the maintenance of freight cars, i. e., the cost per 1000 revenue ton miles, and the following table and chart, Fig. 24, shows the maintenance costs on this basis for the same railroads illustrated in this chapter.

The chart shows a variation in maintenance from 39.1 cents per 1,000 revenue ton miles on the Norfolk & Western to 93.6 on the Denver & Rio Grande, a difference of 139 per cent.

This is not, however, a satisfactory basis of comparison as the revenue to miles do not include the empty car mileage or the transportation of Company material and the omission of this data renders the information quite incomplete.

For instance: in 1911 the empty car miles on the Union Pacific was 25 per cent. of the total car mileage, 26 per cent. on the Atchison, 34 per cent. on the Pennsylvania R. R. and 35 per cent. on the Reading. Empty cars in service are subject to the wear and tear of traffic and depreciation in approximately the same ratio as cars in revenue service.

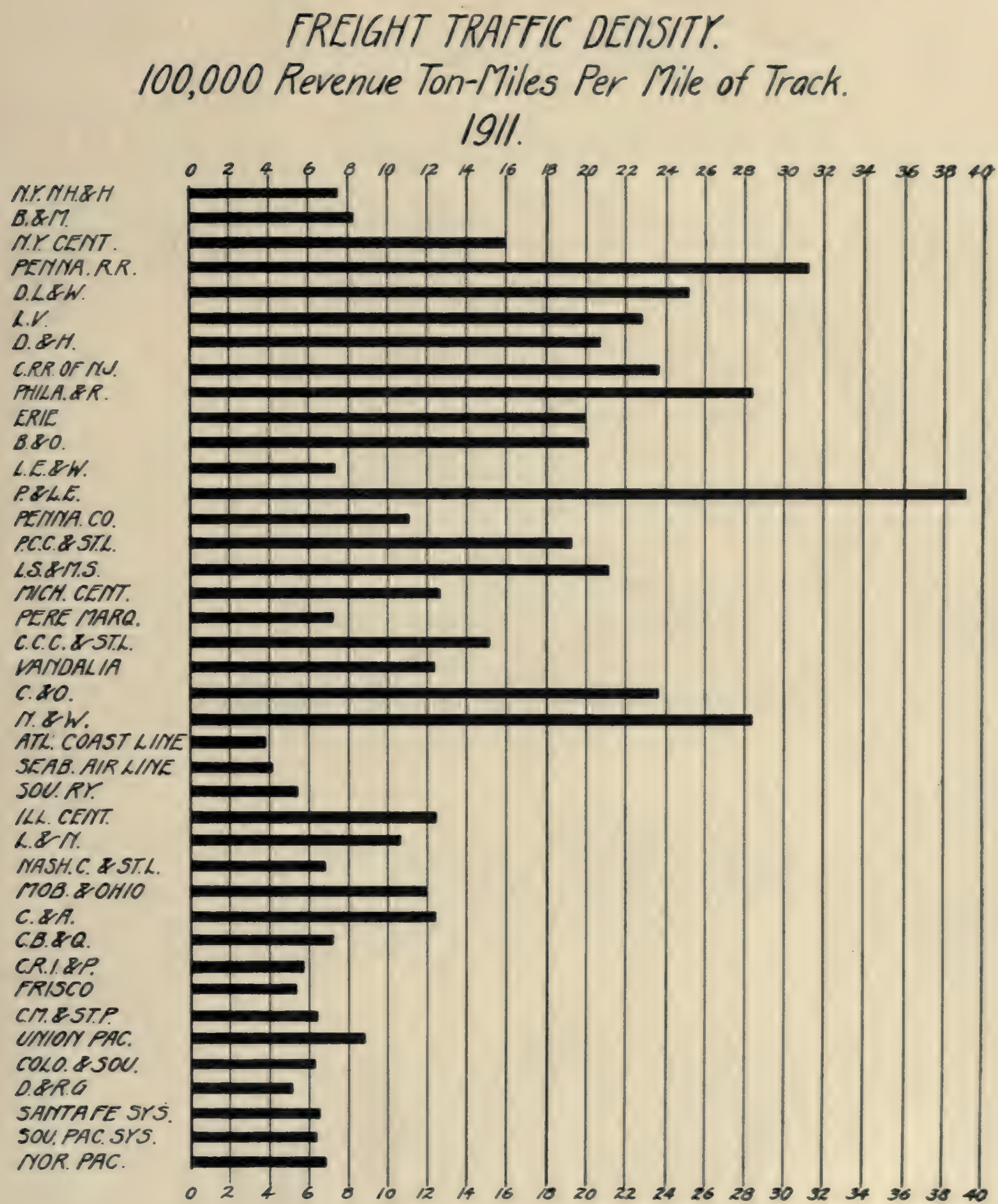

FREIGHT TRAFFIC DENSITY.
100,000 Revenue Ton-Miles Per Mile of Track.
1911.
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
N.Y. N.H.&H
B.&M.
N.Y. CENT.
PENNA. R.R.
D.L.&W.
L.V.
D.&H.
C.R.R. OF N.J.
PHILA.&R.
ERIE
B.&O.
L.E.&W.
P.&L.E.
PENNA. CO.
P.C.C.&ST.L.
L.S.&M.S.
MICH. CENT.
PERE MARQ.
C.C.C.&ST.L.
VANDALIA
C.&O.
N.&W.
ATL. COAST LINE
SEAB. AIR LINE
SOU. RY.
ILL. CENT.
L.&N.
NASH.C.&ST.L.
MOB.&OHIO
C.&A.
C.B.&Q.
C.R.I.&P.
FRISCO
C.M.&ST.P.
UNION PAC.
COLO.&SOU.
D.&R.G.
SANTA FE SYS.
SOU. PAC. SYS.
NOR. PAC.
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40

FIG. 23

Likewise, cars carrying company material are under the same service conditions as those revenue freight, when maintenance is considered. Company material is

MAINTENANCE OF FREIGHT CARS—PER 1,000 REVENUE TON MILES

1911

	Cents		Cents
N. Y. N. H. & H.	71.7	C. & O.	46.3
B. & M.	73.3	N. & W.	39.1
N. Y Central	83.8	Atl. Coast Line	91.2
Penn. R. R.	52.0	Seab. Air Line	70.6
D. L. & W.	45.7	Southern	75.1
Leh. Valley	48.8	Ill. Central	74.7
D. & H.	48.4	L. & N.	65.9
C. R. R. of N. J.	54.4	Nash. C. & St. L.	90.4
P. & R.	88.3	Mob. & Ohio	56.9
Erie	49.1	C. & A.	56.1
B. & O.	47.3	C. B. & Q.	67.5
L. E. & W.	73.7	C. R. I. & P.	70.3
P. & L. E.	50.7	Frisco	74.8
Penna. Co.	56.3	C. M. & St. P.	68.1
P. C. C. & St. L.	69.2	Union Pac.	46.4
L. S. & M. S.	61.3	Colo. & Sou.	74.7
Mich. Central	71.4	D. & R. G.	93.6
Pere Marq.	55.9	Santa Fe Sys.	59.0
C. C. C. & St. L.	67.7	Sou. Pac. Sys.	80.5
Vandalia	67.6	Nor. Pac.	50.1

an extensive traffic item. During the fiscal year 1910, the net ton miles of Company material on the Southern Pacific was equal to 20 per cent. of the revenue ton miles, while on the Atchison it was 32 per cent. Failure to consider the empty car mileage or the mileage made in non-revenue service in making comparisons of maintenance, will result in erroneous conclusions.

To permit the influence of these two items on the total miles run to be more thoroughly appreciated, the following data covering the freight car density, i. e., 10,000 freight car miles per mile of total track, is shown and also illustrated in Fig. 25.

The variation in this table is from 3.99 on the Denver & Rio Grande to 19.85 on the Pittsburg & Lake Erie. A comparison of Figures 23 and 25 is very interesting, particularly the New York Central with the Delaware & Hudson, the Pennsylvania with the Lackawanna, the Lehigh Valley with the Central Railroad of New Jersey, and the Santa Fe with the Northern Pacific.

The maintenance of freight cars, as has been previously pointed out should be proportional to the distance hauled and for the purpose of continuing the study,

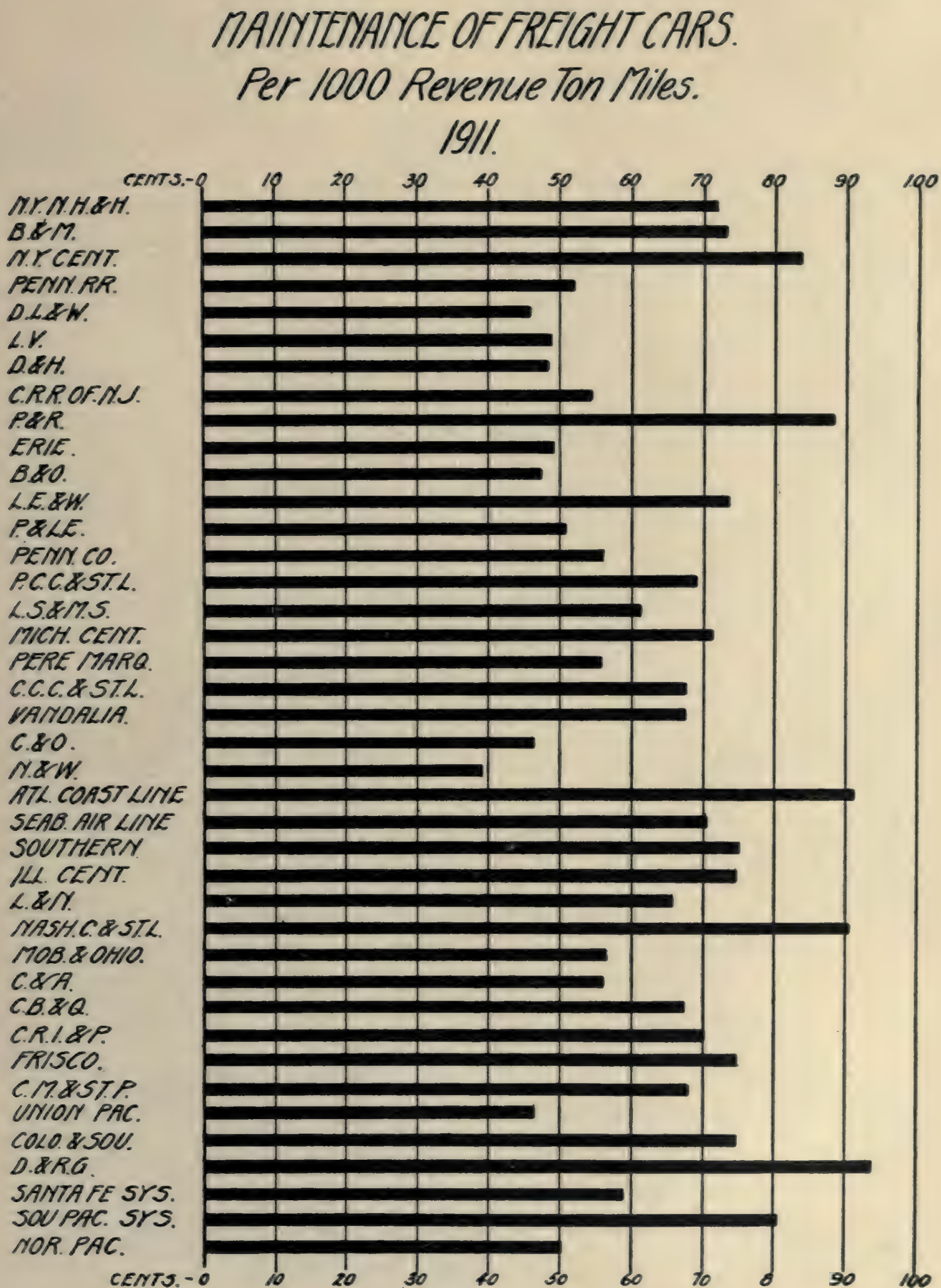

MAINTENANCE OF FREIGHT CARS.
Per 1000 Revenue Ton Miles.
1911.
CENTS.-0 10 20 30 40 50 60 70 80 90 100
N.Y. N.H.&H.
B.&M.
N.Y. CENT.
PENN. RR.
D.L.&W.
L.V.
D.&H.
C.R.R. OF N.J.
P.&R.
ERIE.
B.&O.
L.E.&W.
P.&L.E.
PENN. CO.
P.C.C.&ST.L.
L.S.&M.S.
MICH. CENT.
PERE MARQ.
C.C.C.&ST.L.
VANDALIA.
C.&O.
N.&W.
ATL. COAST LINE
SEAB. AIR LINE
SOUTHERN
ILL. CENT.
L.&N.
NASH.C.&ST.L.
MOB.&OHIO.
C.&A.
C.B.&Q.
C.R.I.&P.
FRISCO.
C.M.&ST.P.
UNION PAC.
COLO.&SOU.
D.&R.G.
SANTA FE SYS.
SOU PAC. SYS.
NOR. PAC.
CENTS.- 0 10 20 30 40 50 60 70 8 90 100

FIG. 24

FREIGHT CAR DENSITY. 10,000 FREIGHT CAR MILES—PER MILE OF TRACK

1911

N. Y. N. H. & H.	$ 7.04	C. & O.	$ 12.92
B. & M.	8.03	N. & W.	16.82
N. Y. Central	14.35	Atl. Coast Line	4.70
Penna. R. R.	18.47	Seab. Air Line	4.63
D. L. & W.	17.45	Southern	5.65
Leh. Valley	15.28	Ill. Central	10.16
D. & H.	13.02	L. & N.	8.34
C. R. R. of N. J.	14.70	Nash. C. & St. L.	7.11
P. & R.	18.88	Mob. & Ohio	10.39
Erie	14.00	C. & A.	9.73
B. & O.	13.98	C. B. & Q.	6.29
L. E. & W.	5.85	C. R. I & P.	5.81
P. & L. E.	19.85	Frisco	5.06
Penna. Co.	17.38	C. M. & St. P.	6.50
P. C. C. & St. L.	14.85	Union Pac.	7.52
L. S. & M. S.	15.61	Colo. & Sou.	4.23
Mich. Central	11.93	D. & R. G.	3.99
Pere Marq.	5.82	Sante Fe Sys.	6.77
C. C. C. & St. L.	12.19	Sou. Pac. Sys.	5.65
Vandalia	9.47	Nor. Pac.	5.04

the following data is submitted and illustrated in Fig. 26, showing the maintenance cost per 1,000 freight car miles for the same railroads.

In this table, the extremes are the Union Pacific, with a maintenance cost of $5.54 per 1,000 freight car miles and the Reading with $13.47 per 1,000 car miles, a difference of 143 per cent.

While this unit is not sufficiently comprehensive to include all influencing factors, it is the best basis for comparing these maintenance costs that is now available. Comparisons on the basis of miles run are unsatisfactory due to not taking into consideration the variation in the weight of the cars.

If the gross ton miles were reported by the railroads to the Interstate Commerce Commission (which information would reflect the total weight of both revenue and company material, the weight of cars whether loaded or empty and the distance hauled), this unit, i. e., the gross ton mile, would be far more satisfactory for comparing maintenance costs than any now employed.

Other important factors entering into the maintenance of freight cars, besides the size and loading of the cars and the miles run, are the design and material in construction, the age of the equipment and class of traffic handled.

Many railroads have the majority of their cars of all steel construction, while others prefer to have steel underframes with wooden bodies. Other railroads, in order to have this portion of their rolling stock able to withstand the stress of heavy tonnage, equip their wooden cars with steel re-inforcements, which with the addition of cars of all wooden construction gives four distinct types of cars. It is

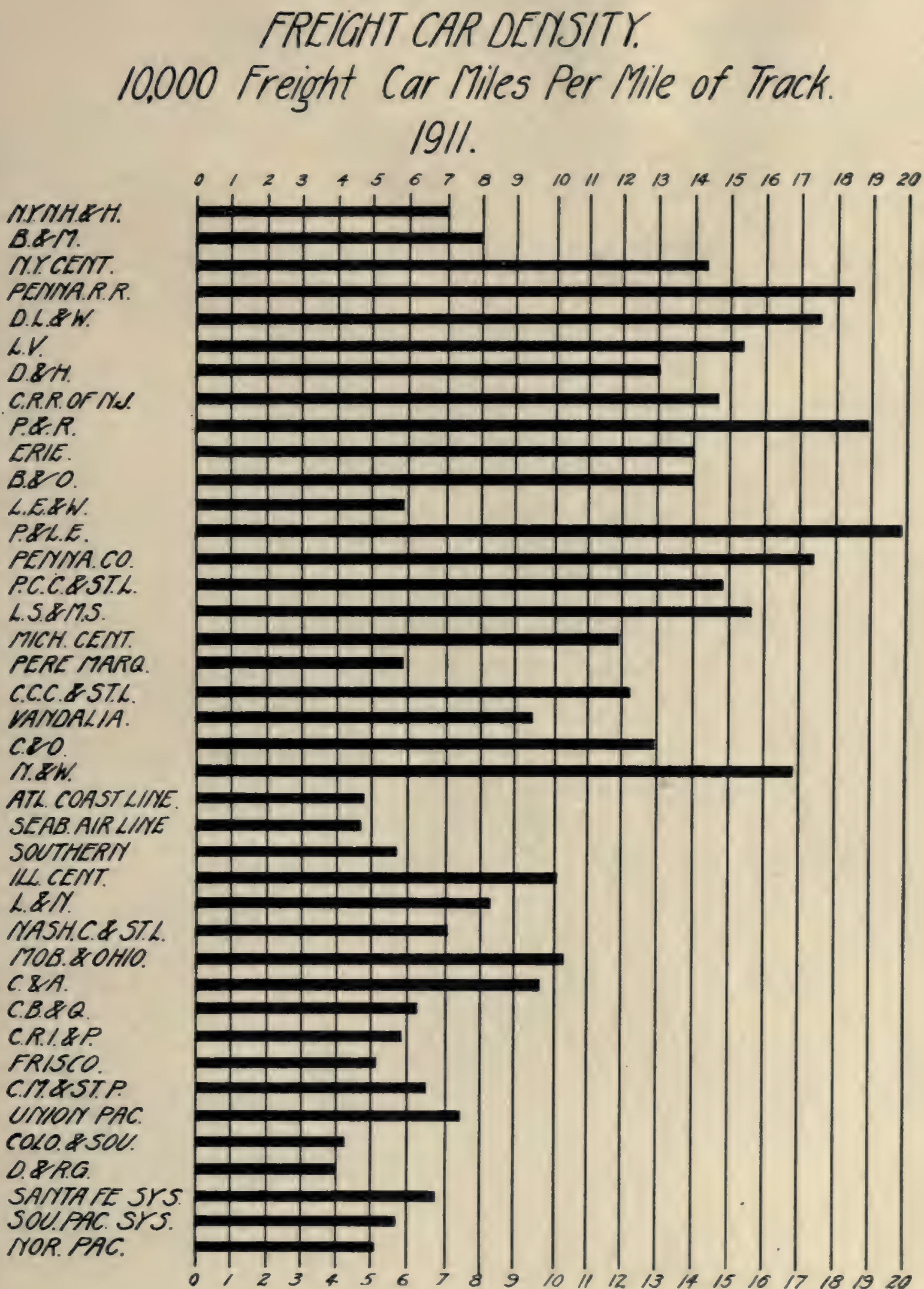

FREIGHT CAR DENSITY.
10,000 Freight Car Miles Per Mile of Track.
1911.
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
N.Y.N.H.&H.
B.&M.
N.Y.CENT.
PENNA.R.R.
D.L.&W.
L.V.
D.&H.
C.R.R. OF N.J.
P.&R.
ERIE.
B.&O.
L.E.&W.
P.&L.E.
PENNA.CO.
P.C.C.&ST.L.
L.S.&M.S.
MICH. CENT.
PERE MARQ.
C.C.C.&ST.L.
VANDALIA.
C.&O.
N.&W.
ATL. COAST LINE.
SEAB. AIR LINE
SOUTHERN
ILL. CENT.
L.&N.
NASH.C.&ST.L.
MOB.&OHIO.
C.&A.
C.B.&Q.
C.R.I.&P.
FRISCO.
C.M.&ST.P.
UNION PAC.
COLO.&SOU.
D.&R.G.
SANTA FE SYS.
SOU.PAC. SYS.
NOR. PAC.
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

FIG. 25

MAINTENANCE OF FREIGHT CARS—PER 1,000 FREIGHT CAR MILES

1911

N. Y. N. H. & H.	$ 7.31	C. & O.	$ 8.47
B. & M.	7.66	N. & W.	6.71
N. Y. Central	9.35	Atl Coast Line	7.63
Penna. R. R.	8.84	Seab. Air Line	6.70
D. L. & W.	6.68	Southern	7.46
Leh. Valley	7.34	Ill. Central	9.25
D. & H.	7.75	L. & N.	8.46
C. R. R. of N. J.	8.82	Nash. C. & St. L.	8.83
P. & R.	13.47	Mob. & Ohio	6.60
Erie	7.03	C. & A.	7.25
B. & O.	6.89	C. B. & Q.	7.90
L. E. & W.	9.28	C. R. I. & P.	7.09
P. & L. E.	10.33	Frisco	8.11
Penna Co.	9.19	C. M. & St. P.	7.05
P. C. C. & St. L.	9.08	Union Pacific	5.54
L. S. & M. S.	8.49	Colo. & Sou.	11.28
Mich. Central	7.79	D. & R. G.	12.31
Pere Marq.	7.02	Santa Fe Sys.	6.07
C. C. C. & St. L.	8.55	Sou. Pac. Sys.	9.47
Vandalia	9.14	Nor. Pac.	6.95

evident that the type of cars used on the various railroads will have important bearing on the maintenance costs.

The extent to which the standardization of equipment has been carried must also be considered, as those railroads having equipment with standard parts will be able to maintain their cars at considerable less cost for material than those whose equipment is not standardized. Since material constitutes approximately 70 per cent. of the total freight car maintenance, this item is a most important one.

Unfortunately, the Interstate Commerce Commission records do not provide for any segregation of maintenance costs between labor and material, although this information is necessary in order to make a complete study.

The topography of the country also has a substantial influence on the maintenance of cars, since the service conditions are far more severe on cars when handled over mountain grades than in a level country. In making any analysis between two railroads, the question of grades must be given consideration.

By far the most important item affecting freight car maintenance, and one which heretofore has not been considered is the influence of the interchange of cars.

In order to facilitate the handling of traffic, the leading railroads have standard rules of interchange of cars which practice permits much of the freight car mileage on any railroad to be made by foreign cars.

This is a particularly large item with roads having traffic connections like the Union Pacific, Lehigh Valley, Vandalia and P. C. C. & St. L In 1910, the foreign

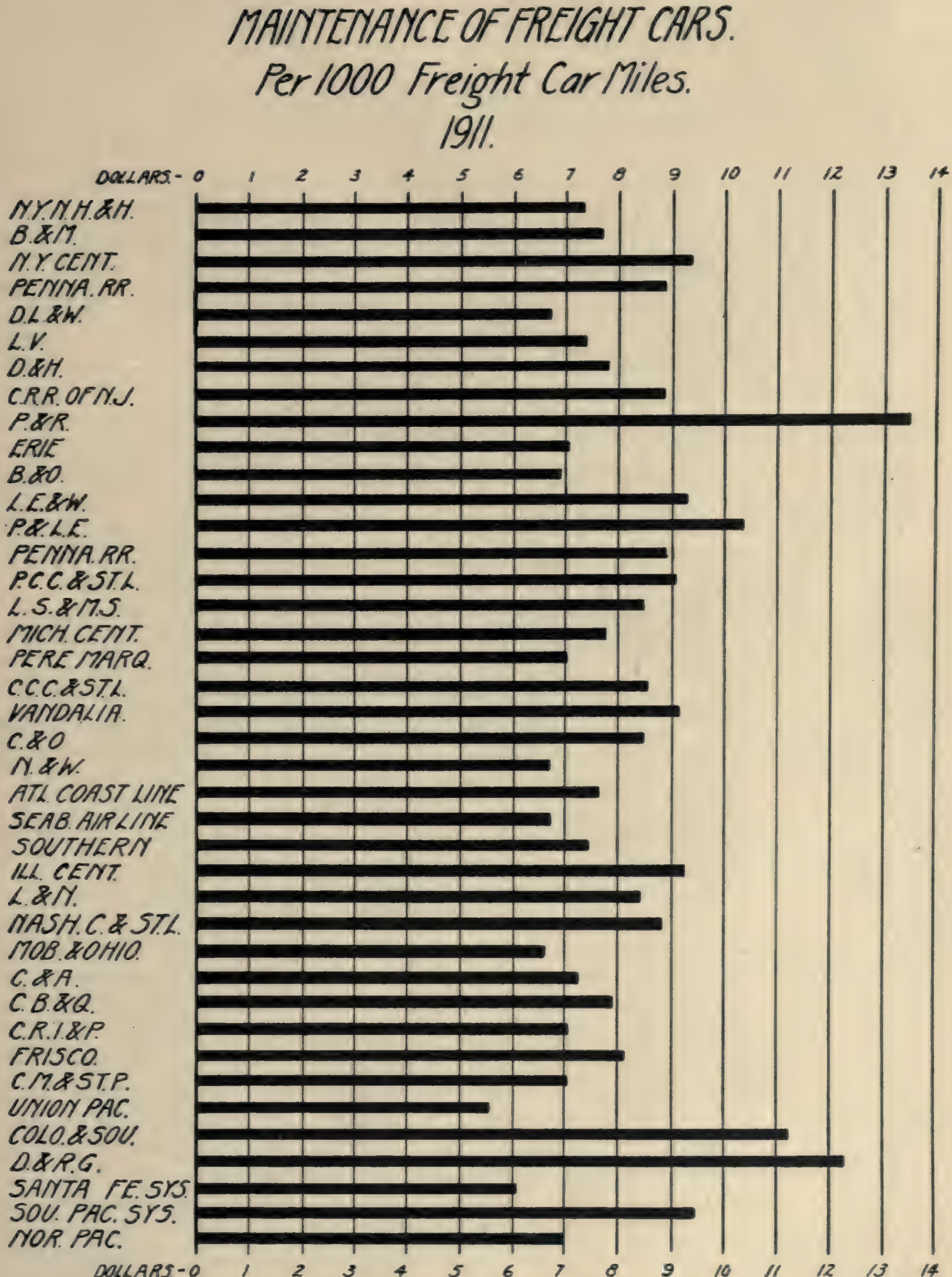

MAINTENANCE OF FREIGHT CARS.
Per 1000 Freight Car Miles.
1911.
DOLLARS - 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
N.Y.N.H.&H.
B.&M.
N.Y. CENT.
PENNA. RR.
D.L.&W.
L.V.
D.&H.
C.R.R. OF N.J.
P.&R.
ERIE
B.&O.
L.E.&W.
P.&L.E.
PENNA. RR.
P.C.C.&ST.L.
L.S.&M.S.
MICH. CENT.
PERE MARQ.
C.C.C.&ST.L.
VANDALIA.
C.&O
N.&W.
ATL. COAST LINE
SEAB. AIR LINE
SOUTHERN
ILL. CENT.
L.&N.
NASH. C.&ST.L.
MOB.&OHIO.
C.&A.
C.B.&Q.
C.R.I.&P.
FRISCO.
C.M.&ST.P.
UNION PAC.
COLO.&SOU.
D.&R.G.
SANTA FE SYS.
SOU. PAC. SYS.
NOR. PAC.
DOLLARS - 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

FIG. 26

car mileage on the Union Pacific was approximately 81 per cent. of the total car mileage.

In connection with the interchange of cars there is an agreement between the railroads as to what repairs the owner shall be responsible for, while their cars are on foreign lines, the balance of the repairs being borne by the railroad directing their movement.

Where the interchange of traffic is sufficient to make the foreign car mileage an important item on any railroad, it is evident the method employed in making repairs to foreign cars and the billing for this service must necessarily influence the total freight car maintenance. In the records of the Interstate Commerce Commission, this data is not on file and as a consequence nothing can be done in continuing a study in this respect.

In conjunction with the rules governing the interchange of cars and repairs, there is also an agreement that the railroad handling a foreign car shall pay the owner a service rental for each day the car is on that particular road. On a road like the Union Pacific with over 80 per cent. of the total car mileage made by foreign cars, the per diem rental is of considerable importance in the cost of freight operation.

It also follows that a road so situated, that it can control a large amount of interchange, will find it unnecessary to own a great number of cars, while railroads doing largely a local business must necessarily carry a heavy equipment investment.

In order that such a study can be conducted satisfactorily, it will be necessary to know the total amounts paid by a railroad for foreign car service and also the total mileage made by these cars.

Another item which influences the number of cars owned in addition to the effect of interchange of traffic, is the extent to which the cars are out of service. Gravity yards, which facilitate the handling of traffic, greatly increase the number of cars to be repaired. The same conditions exist in hauling cars over heavy mountain grades.

To make a thorough analysis, it will be necessary to know the number of cars held for repairs each day or the average time the cars are out of service for such repairs.

A careful study of the voluminous data and illustrative charts submitted in connection with this treatise on freight car maintenance, results in the full realization that the present data is entirely insufficient to permit a conclusive study of this, the largest item of maintenance of equipment expenditures.

There is at present no satisfactory unit to be used with the available data that will afford opportunity for the analyst to make such deductions as will be of value.

No suggestions, therefore, can be made at this time for the purpose of assisting railroad operating officials in determining the best design and type of construction, the best methods of operation and the best practices in maintenance to attain the highest efficiency in this particular part of railroad operation.

It is hoped, however, that the suggestions contained herein will be reviewed with approval by the Interstate Commerce Commission and that such data will be secured as will make future studies of freight car maintenance, educative and instructive.

Locomotive Maintenance

CHAPTER V.

The maintenance of locomotives, exclusive of depreciation charges on all the railroads in the United States in 1911, was equivalent to 8.0 per cent. of the total operating expenses. This percentage of operating expenses in that year ranged from 5.8 per cent. on the Northern Pacific to 11.5 per cent. on the D. & R. G., and on seven railroads this item constituted more than 10 per cent. of the total operating expenses.

Inasmuch as 35 per cent. of the total maintenance of equipment expenses are charged to repairs and renewals of locomotives, these costs should be studied very carefully before any conclusions are drawn with reference to the efficiency of performance.

The usual method of comparing locomotive maintenance costs is on the basis of the annual expenditure per locomotive, this form being used in practically all of the annual reports of railroad presidents and all analyses of operating expenses.

In a preceding chapter, figures were given showing an average increase of 33 per cent. in the tractive force of locomotives in the 9 years ending 1910. In the year 1911, the average tractive force per locomotive varied from 20,564 pounds on the Atlantic Coast Line to 33,830 pounds on the Chicago, Milwaukee & Puget Sound—a difference of 74 per cent.

Larger and heavier locomotives are bound to require higher maintenance expenses than those of smaller size, and with such a variation in the average weight of locomotives, it is evident that the employment of "the locomotive" as a comparative unit is far from satisfactory.

That comparisons of this nature are erroneous is emphasized by the record of locomotive maintenance on the Atchison, where the cost per locomotive was 48 per cent. higher in 1910 than in 1901, which would indicate, if the locomotive is the proper unit, that repairs had increased at an enormous and extravagant rate. In the meantime, however, the average weight increased 37 per cent.; the average tractive force increased 41 per cent.; and the maintenance cost per ton of tractive force decreased 4 per cent.

Another factor which would tend to destroy the value of the locomotive as the comparative unit is the fact that the average miles run by locomotives may vary considerably on different railroads. In 1911, for example, the average miles "per locomotive owned" on the Erie was 21,856 miles, while the average on the P. C. C. & St. L. was 37,272—a difference of 70 per cent. If comparisons of maintenance costs are to be made on the basis of the average cost "per locomotive," it is apparent that the railroad with the smallest locomotives and running the least number of

miles will possess considerable advantage. Such figures are of no value whatever for comparative purposes.

On some railroads an effort is made to carry this comparison to a more satisfactory conclusion, and comparisons are made on the basis of "per locomotive mile." However, these comparisons are but little more satisfactory than on the basis "per locomotive" since the size of the locomotive is not considered, and with a variation of 74 per cent. in average weight the relative size exerts considerable influence.

The gross ton mile is the most satisfactory unit, since this combines the total tonnage and the distance hauled, but this data is not available since railroads do not report this to the Interstate Commerce Commission. Any comparisons, however, must take into consideration operating conditions, particularly grades and speed of trains in making a final analysis.

A unit should be used which takes into consideration the power developed and the work delivered by the locomotive. The engine which propels the steamship is rated in horse-power and the performance is calculated in horse-power hours. Electric power units are similarly rated in Watts and the work performed is given in watt-hours.

Maintenance costs on electric equipment are not calculated as so much per dynamo or motor, but based on the work done—the watt-hours. It is therefore decidedly reasonable to expect to show locomotive costs on a similar basis. Tractive force or draw-bar pull is the usual term to express the power of a locomotive, and a satisfactory work unit (which may be called the tractive mile) is the product of the tractive force and mileage made.

To illustrate the value of the tractive mile or work unit as a basis of comparison of maintenance costs, the following study is made covering a period of years on a number of representative railroads. This information was compiled by the Interstate Commerce Commission at the recent rate hearing. Charts and also the actual figures are presented giving exhibits of six representative eastern and six western railroads, showing locomotive maintenance costs.

Repairs and Renewals of Locomotives per Locomotive.

Eastern Roads	Average 4 Yrs. Ending 1905	Average 5 Yrs. Ending 1910	Per Cent. Increase
N. Y. Central	$2,150	$2,430	13.0%
Penn. Railroad	2,340	2,640	12.8
D. L. & W.	1,480	1,690	14.2
B. & O.	2,370	2,440	3.0
Wabash R. R.	2,530	2,580	2.0
Lehigh Valley	2,670	2,690	1.0
Western Roads			
C. M. & St. P.	$1,365	$2,150	57.5%
C. R. I. & P.	1,840	2,330	26.6
C. & N. W.	1,660	2,010	21.1
C. B. & Q.	2,320	2,620	13.0
C. & A.	2,300	2,595	12.8
A. T. & S. F.	2,600	2,720	4.6

The average cost of repairs and renewals of locomotives "per locomotive" for five years ending 1910, compared with four years ending 1905, is presented in Fig. 27.

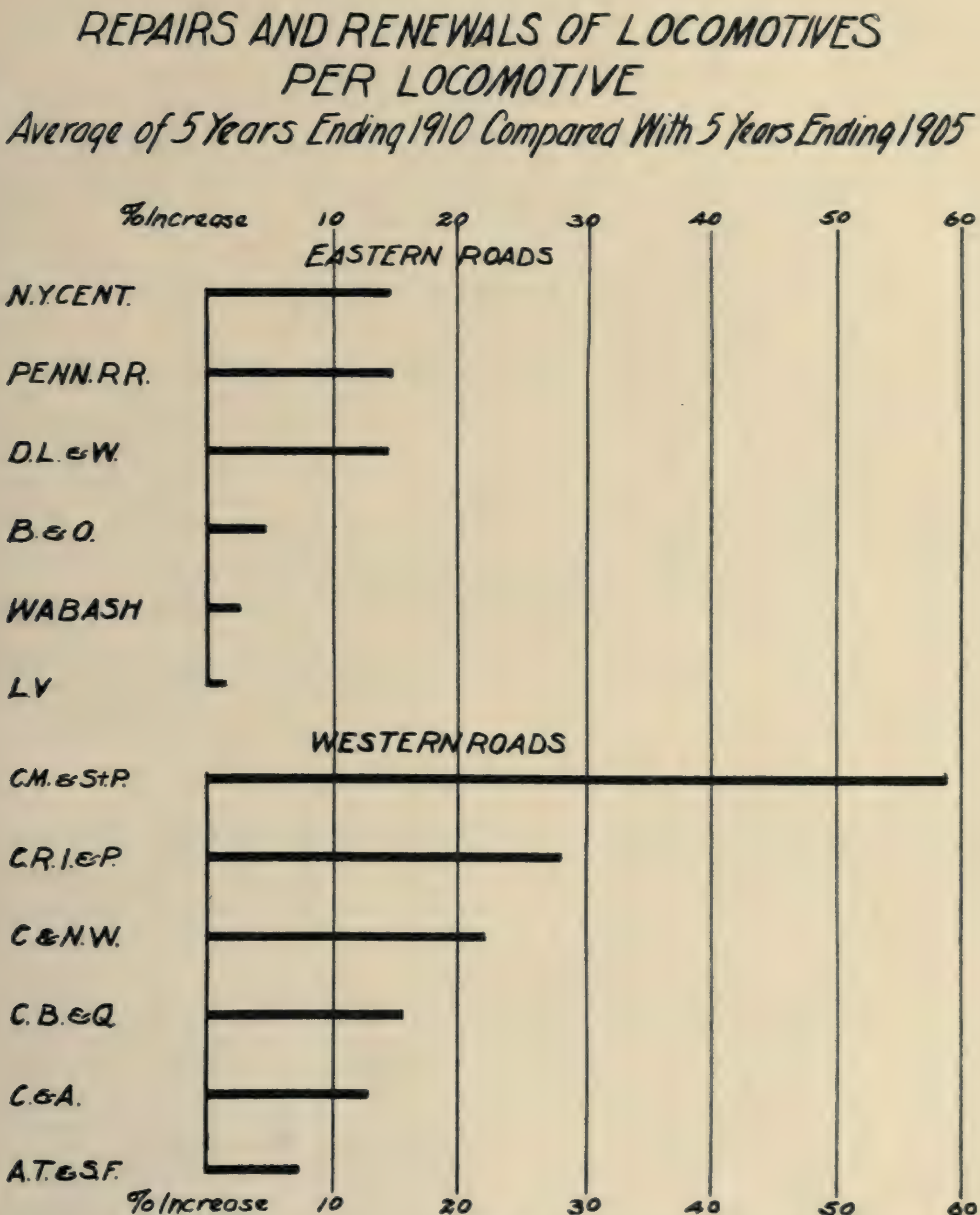


FIG. 27

The increases on the eastern railroads range from 1.0 per cent. on the Lehigh Valley to 13 per cent. on the New York Central. On the western roads the increases range from 4.6 per cent. on the Atchison to 57.5 per cent. on the St. Paul.

Fig. 28 illustrates the increase in repairs and renewals of locomotives "per locomotive mile" during the above-mentioned period.

REPAIRS AND RENEWALS OF LOCOMOTIVES PER LOCOMOTIVE MILE.

Eastern Roads	Average 4 Yrs. Ending 1905	Average 5 Yrs. Ending 1910	Per Cent. Increase
N. Y. Central..............	5.65 cents	7.81 cents	38.2%
D. L. & W...............	4.24	5.49	29.5
Penna. Railroad...........	7.72	9.78	26.7
Wabash	6.23	7.65	22.8
B. & O...................	6.98	7.67	10.0
Lehigh Valley............	10.37	10.80	4.2
Western Roads			
C. M. & St. P.............	3.46 cents	5.36 cents	55.0%
C. R. I. & P..............	6.20	8.22	32.6
C. B. & Q................	6.78	9.07	33.6
C. & N. W...............	4.34	5.68	31.0
C. & A...................	6.28	7.76	23.6
A. T. & S. F..............	9.73	10.19	4.7

The New York Central shows an increase of 38 per cent. and the St. Paul an increase of 55 per cent., while the Lehigh Valley and the Atchison increased less than 5 per cent.

The costs when calculated on the basis of tractive force (a more satisfactory unit than the other two just used), averaged for five years ending 1910, are shown in Fig. 29.

REPAIRS AND RENEWALS OF LOCOMOTIVES PER TON TRACTIVE FORCE.

Eastern Roads	Average 4 Yrs. Ending 1905	Average 5 Yrs. Ending 1910	Per Cent. Increase	Per Cent. Decrease
D. L. & W........	$121.00	$133.00	10.0%	....
Penna. Railroad....	181.00	169.00	.....	6.6%
N. Y. Central......	191.00	170.00	.....	11.0
B. & O...........	182.00	158.00	.....	13.2
Lehigh Valley.....	241.00	200.00	.....	17.0
Wabash	280.00	228.00	.....	18.5
Western Roads				
C. M. & St. P......	$172.00	$217.00	26.2%	....
C. R. I. & P.......	180.00	185.00	2.8	....
C. & N. W........	189.00	191.00	1.0	....
C. & A............	198.00	186.00	....	6.1%
C. B. & Q.........	246.00	223.00	....	9.3
A. T. & S. F.......	219.00	182.00	....	16.9

REPAIRS AND RENEWALS OF LOCOMOTIVES PER LOCOMOTIVE MILE.

Average of 5 Years Ending 1910 Compared with 5 Years Ending 1905.

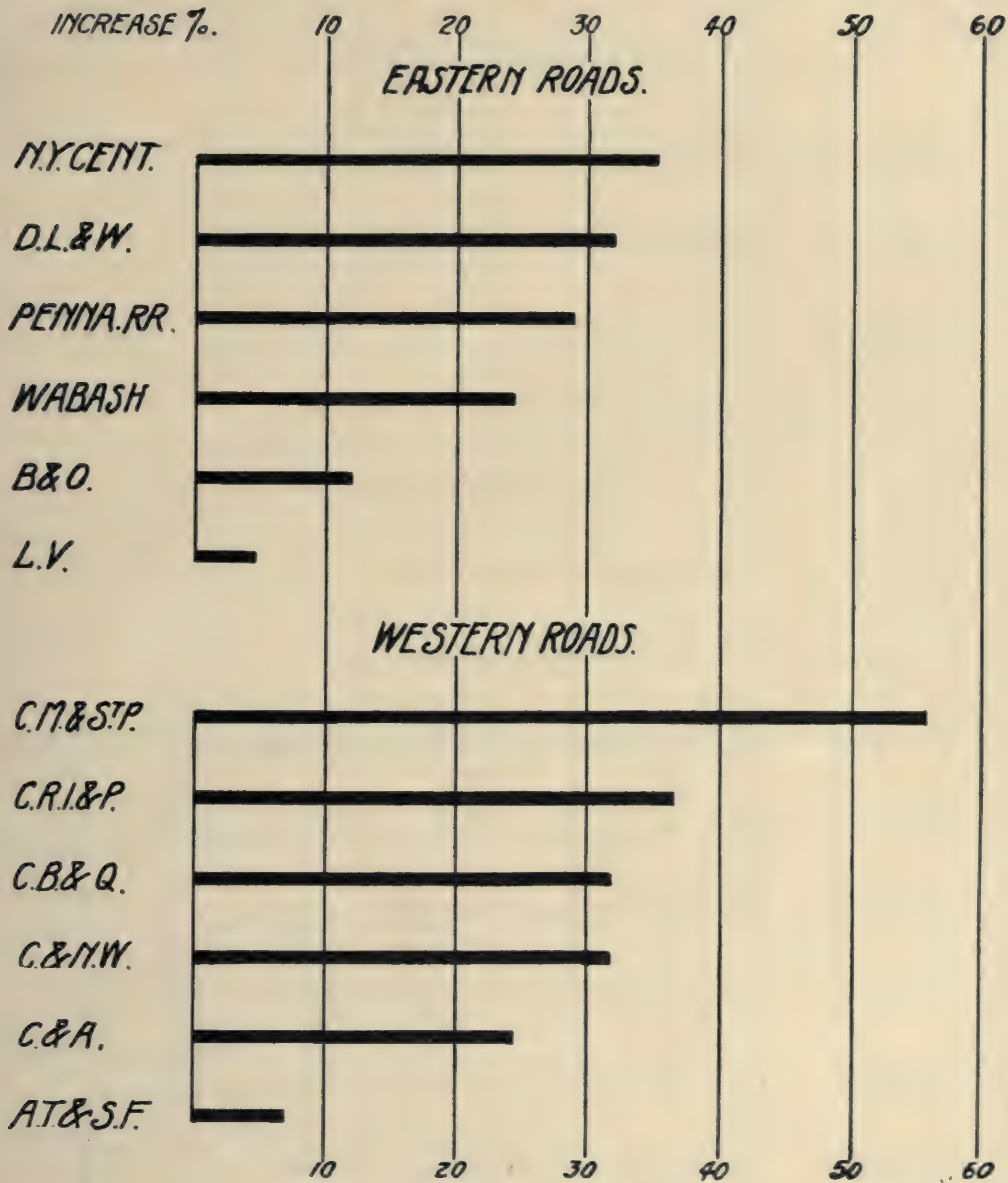


Fig. 28

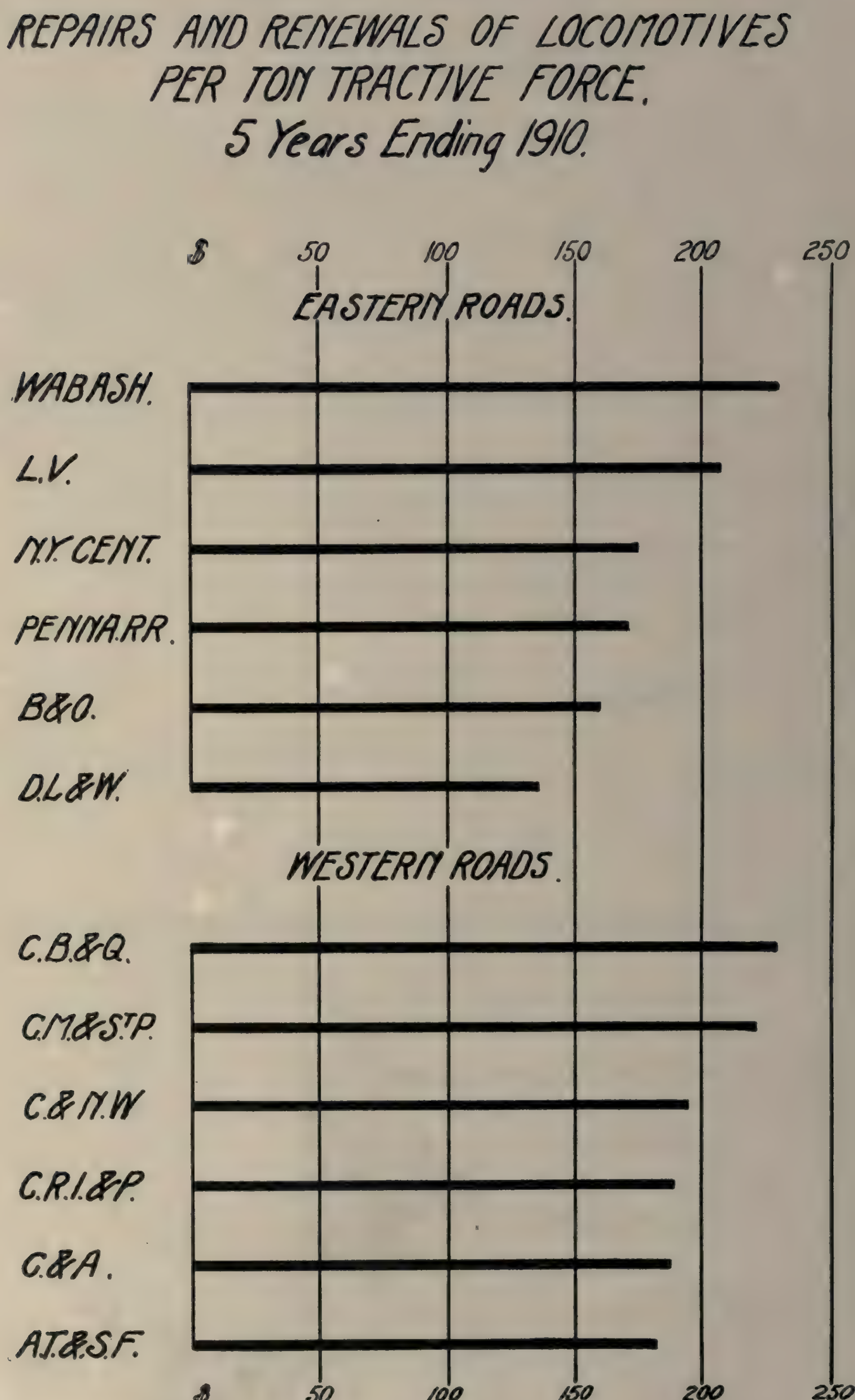

REPAIRS AND RENEWALS OF LOCOMOTIVES
PER TON TRACTIVE FORCE.
5 Years Ending 1910.
$
50
100
150
200
250
EASTERN ROADS.
WABASH.
L.V.
N.Y. CENT.
PENNA.R.R.
B.&O.
D.L.&W.
WESTERN ROADS.
C.B.&Q.
C.M.&St.P.
C.&N.W.
C.R.I.&P.
C.&A.
A.T.&S.F.
$
50
100
150
200
250

Fig. 29

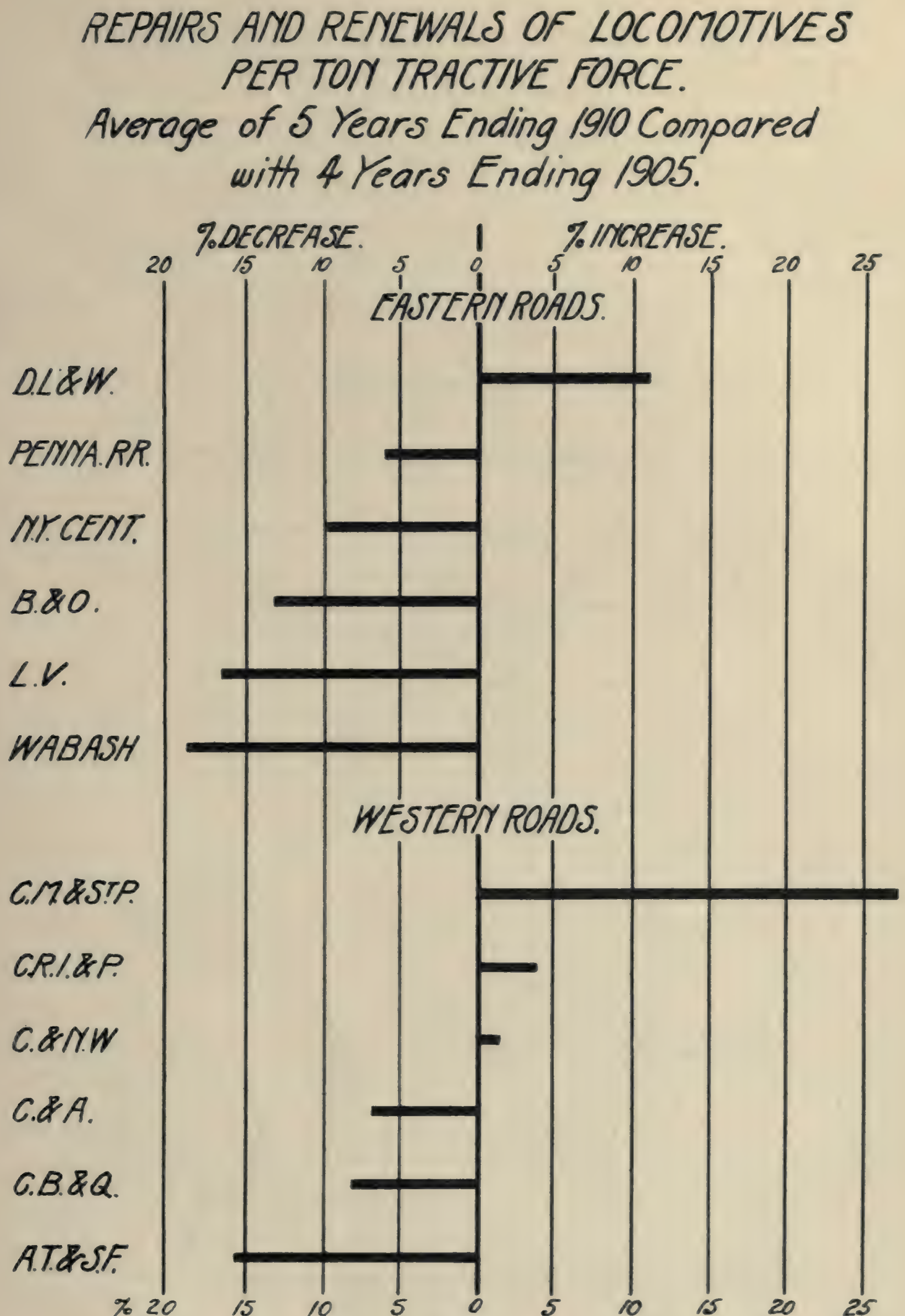

REPAIRS AND RENEWALS OF LOCOMOTIVES
PER TON TRACTIVE FORCE.
Average of 5 Years Ending 1910 Compared
with 4 Years Ending 1905.
% DECREASE.
% INCREASE.
20 15 10 5 0 5 10 15 20 25
EASTERN ROADS.
D.L.&W.
PENNA.R.R.
N.Y. CENT.
B.&O.
L.V.
WABASH
WESTERN ROADS.
C.M.&ST.P.
C.R.I.&P.
C.&N.W.
C.&A.
C.B.&Q.
A.T.&S.F.
% 20 15 10 5 0 5 10 15 20 25

Fig. 30

A comparison of the performance by periods (Fig. 30) for the eastern roads point out the fact that while the Wabash and Lehigh Valley spent the most money per ton of tractive force, they made a decrease of more than 15 per cent. during the five years ending 1910 over the four years ending 1905.

The Lackawanna, on the other hand, while showing the least expenditure per ton of tractive force, actually increased their costs in the five-year period ending 1910 over the previous four years. The western roads show a more nearly equal expenditure, but a wider variation in comparing the two periods. The St. Paul shows an increase of 26.2 per cent. in the five-year period ending 1910 over the four-year period ending 1905; the Atchison shows a decrease of 16.9 per cent. between the same periods.

Repairs and Renewals of Locomotives per Work Unit (Tractive Mile).

Eastern Roads	Average 4 Yrs. Ending 1905	Average 5 Yrs. Ending 1910	Per Cent. Increase	Per Cent. Decrease
D. L. & W.	$1.75	$2.18	24.6%	....
N. Y. Central.......	2.52	2.74	8.7	....
Penna. Railroad.....	3.03	3.14	3.6	....
Wabash	3.48	3.38	....	2.9%
B. & O.............	2.71	2.48	....	8.5
Lehigh Valley.......	4.70	4.02	....	14.5
Western Roads				
C. M. & St. P.......	$2.20	$2.71	23.2%	....
C. B. & Q..........	3.72	4.25	14.2	....
C. & N. W..........	2.48	2.69	8.5	....
C. & A.............	2.73	2.80	2.6	....
C. R. I & P.........	3.36	3.26	....	3.0
A. T. & S. F........	4.21	3.39	....	19.5

The locomotive maintenance costs computed on the "tractive mile" or "work unit" basis (Fig. 31) show that the Lehigh Valley costs are higher but that they have decreased their costs 14.5 per cent. (Fig. 32). The Lackawanna is just the reverse in that their costs are the lowest per "work unit" or "tractive mile," but there is an increase of 24.6 per cent. during the past five years as compared with the four-year period ending 1905. On the western roads there is not the variation noted on the eastern roads in actual costs. However, in comparing the two periods, the extremes are the St. Paul, with an increase of 23.2 per cent., and the Atchison, with a decrease of 19.5 per cent.

The study of the twelve railroads just presented serves to establish the "tractive mile" or "work unit" as a much more satisfactory comparative basis than any used heretofore.

In order to permit the readers to more thoroughly appreciate the situation, and to realize the necessity for a complete revision of existing units of comparison of maintenance costs, the following data for the years 1908, 1909, 1910 and 1911 is presented for many of the representative railroads, viz.:

Maintenance of locomotives, "per locomotive"............Figs. 33 and 34
Average tractive force of locomotives...................Figs. 35 and 36

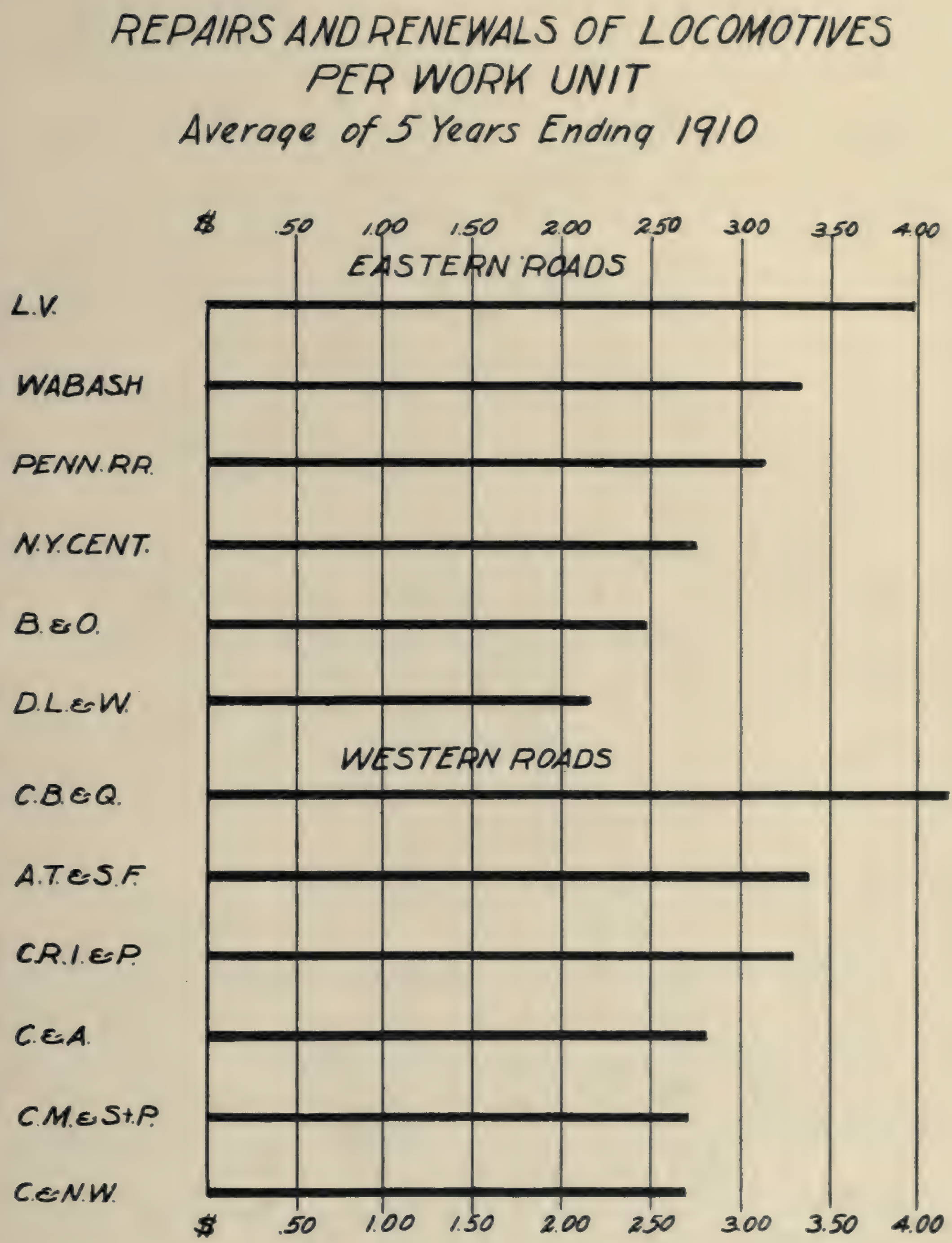

REPAIRS AND RENEWALS OF LOCOMOTIVES
PER WORK UNIT
Average of 5 Years Ending 1910
$ .50 1.00 1.50 2.00 2.50 3.00 3.50 4.00
EASTERN ROADS
L.V.
WABASH
PENN. R.R.
N.Y. CENT.
B. & O.
D.L. & W.
WESTERN ROADS
C.B. & Q.
A.T. & S.F.
C.R.I. & P.
C. & A.
C.M. & St.P.
C. & N.W.
$ .50 1.00 1.50 2.00 2.50 3.00 3.50 4.00

FIG. 31

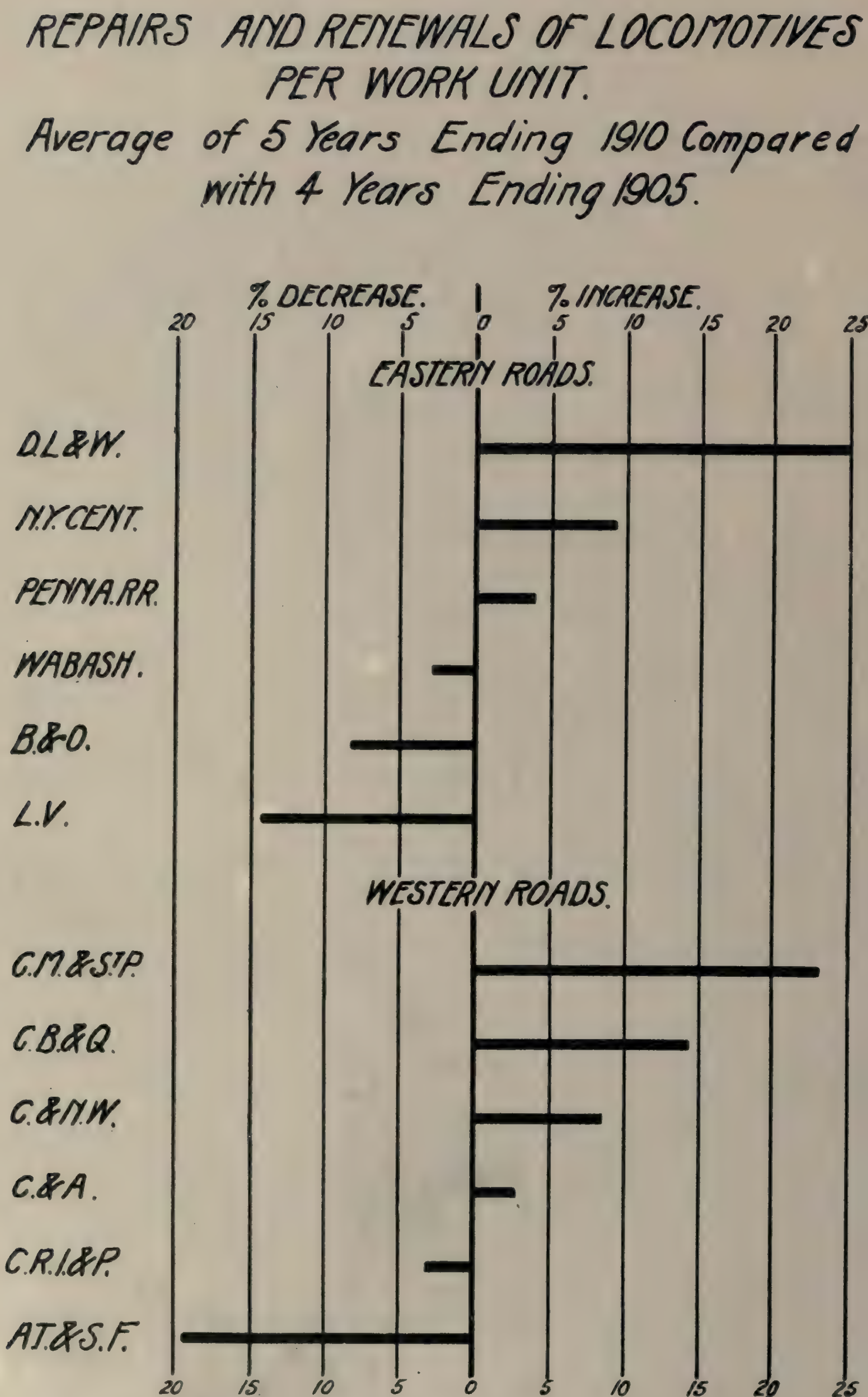

REPAIRS AND RENEWALS OF LOCOMOTIVES PER WORK UNIT.
Average of 5 Years Ending 1910 Compared with 4 Years Ending 1905.
% DECREASE.
% INCREASE.
20 15 10 5 0 5 10 15 20 25
EASTERN ROADS.
D.L.&W.
N.Y.CENT.
PENNA.R.R.
WABASH.
B.&O.
L.V.
WESTERN ROADS.
C.M.&St.P.
C.B.&Q.
C.&N.W.
C.&A.
C.R.I.&P.
A.T.&S.F.
20 15 10 5 0 5 10 15 20 25

Fig. 32

Average miles "per locomotive"........................Figs. 37 and 38
Maintenance of locomotives, "per locomotive mile"........Figs. 39 and 40
Maintenance of locomotives, "per tractive mile"..........Figs. 41 and 42

MAINTENANCE OF LOCOMOTIVES—PER LOCOMOTIVE.

	1908	1909	1910	1911
N. Y. Central	$2,394	$2,110	$2,346	$2,559
Erie	3,520	2,678	2,246	2,210
N. Y. N. H. & H.	1,874	1,540	1,811	2,107
Penn. R. R.	2,758	2,497	2,777	2,865
D. & H.	2,033	2,147	2,996	3,283
D. L. & W.	1,962	1,636	1,762	2,064
C. R. R. of N. J.	2,264	2.203	2,270	2,254
Lehigh Valley	2,649	2,304	2,250	2,212
Phil. & Read	2,700	2,357	2,744	2,788
C. & O.	2,024	2,277	2,464	2,499
Atl. Coast Line	1,597	1,365	1,778	1,970
Seab. Air Line	2,348	2.110	2,252	2,551
Southern	1,907	1,770	2,311	2,338
Lou. & Nash	3,258	2,810	2,968	3,228
Mob. & Ohio	1,458	1,758	2,042	2,440
Nash. C. & St. L.	2,199	2,121	2,340	2,444
P. & L. E.	1,410	1.506	1,655	2,087
L. E. & W.	3,155	3,045	2,889	3,231

MAINTENANCE OF LOCOMOTIVES—PER LOCOMOTIVE.

	1908	1909	1910	1911
P. C. C. & St. L.	$2,595	$2,570	$2,958	$3,256
Vandalia	2,326	2,228	2,789	2,885
C. C. C. & St. L.	2,222	2,319	2,797	2,750
Pere Marq.	1,790	1,832	1,780	2,322
Mich. Central	2,007	2,283	2,234	2,344
Wabash	2,750	2,460	2,814	3.197
Ill. Cent.	2,435	2,670	3,087	3,175
C. & N. W.	1,795	1,930	2,301	2,263
C. B. & Q.	2,025	2,103	2,364	2,164
C. M. & St. P.	1,955	2,000	2,361	2,627
Union Pacific	3,318	3,240	3,687	3,604
Mo. Pac.	1,908	2,870	2,766	3,966
M. K. & T.	2,238	2,682	2,679	2,633
Frisco	2,025	2,390	2,902	2,448
Texas & Pac.	2,059	2,254	2,336	3,165
Colo. & Sou.	2,402	2,658	2,870	2,321
D. & R. G.	2,376	3,313	3,156	3,151
Sou. Pac. Sys.	3,090	3,283	3,702	3,499
Great Nor.	2,075	1.775	2,230	2,280

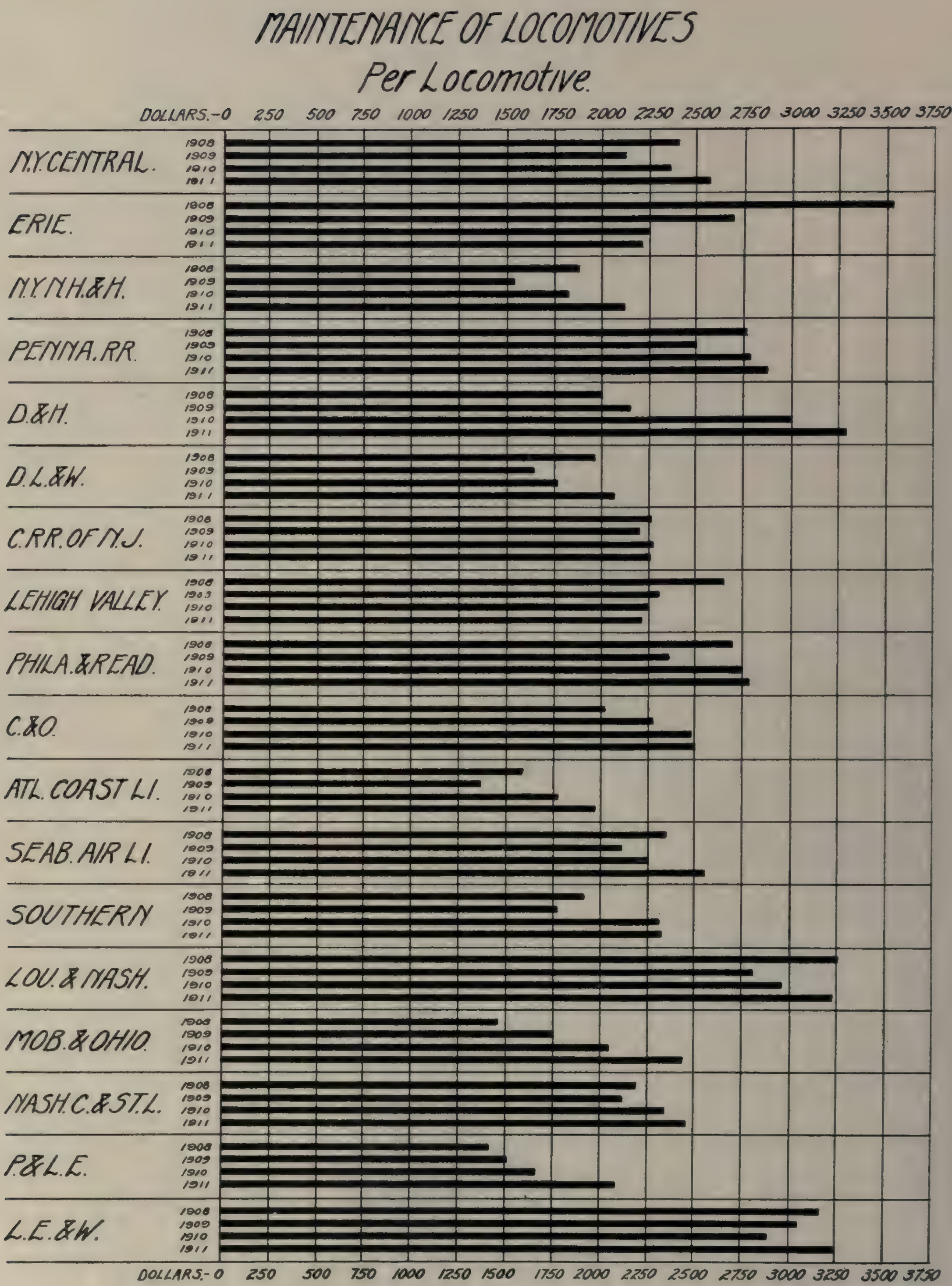

MAINTENANCE OF LOCOMOTIVES
Per Locomotive.
DOLLARS.-0 250 500 750 1000 1250 1500 1750 2000 2250 2500 2750 3000 3250 3500 3750
N.Y.CENTRAL.
ERIE.
N.Y.N.H.&H.
PENNA.RR.
D.&H.
D.L.&W.
C.R.R.OF N.J.
LEHIGH VALLEY
PHILA.&READ.
C.&O.
ATL. COAST LI.
SEAB. AIR LI.
SOUTHERN
LOU.& NASH.
MOB.& OHIO.
NASH.C.&ST.L.
P.&L.E.
L.E.&W.
1908
1909
1910
1911

Fig. 33

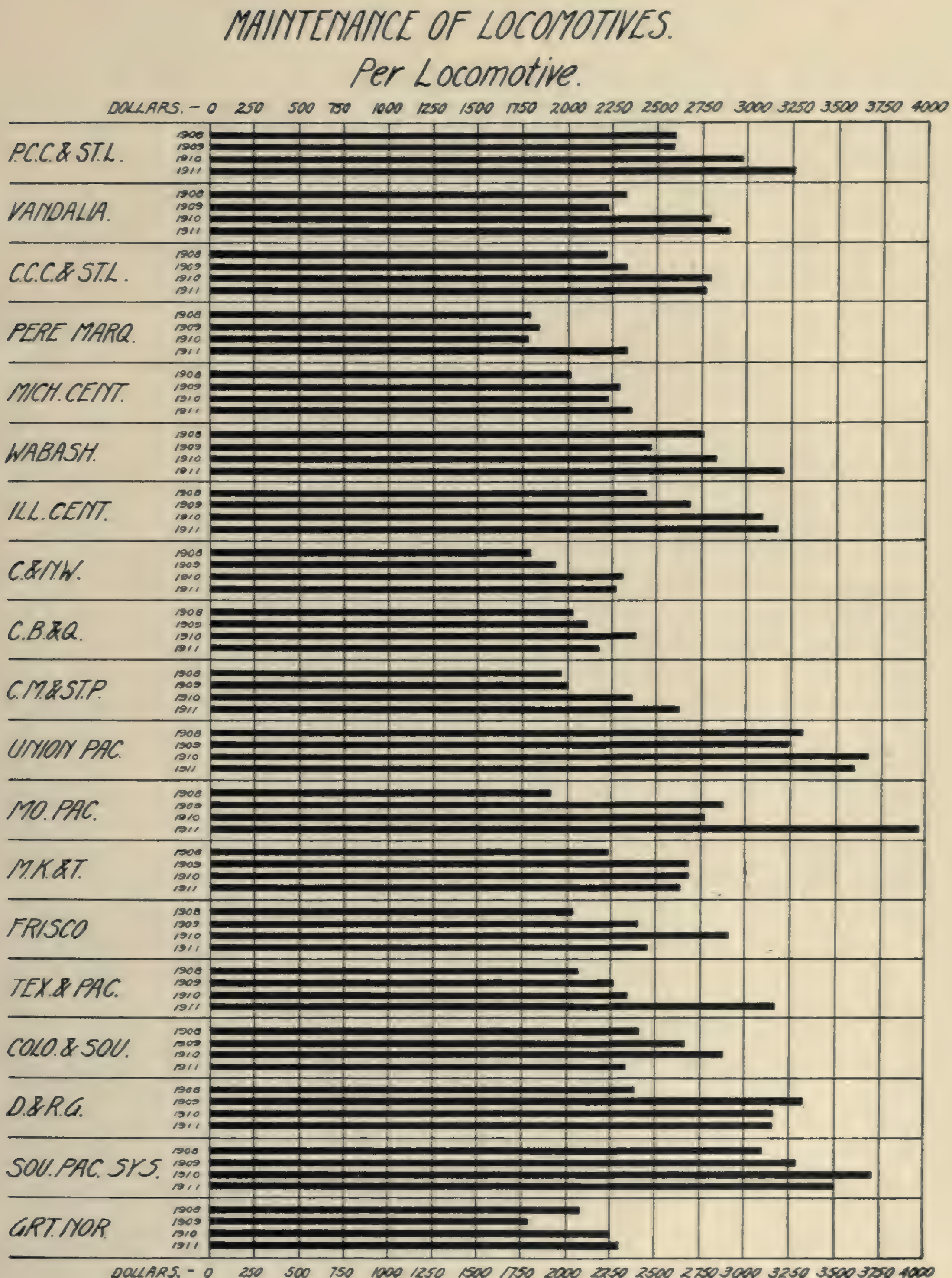

MAINTENANCE OF LOCOMOTIVES.
Per Locomotive.
DOLLARS. – 0 250 500 750 1000 1250 1500 1750 2000 2250 2500 2750 3000 3250 3500 3750 4000
P.C.C.& ST.L.
VANDALIA.
C.C.C.& ST.L.
PERE MARQ.
MICH. CENT.
WABASH.
ILL. CENT.
C.& N.W.
C.B.& Q.
C.M.& ST.P.
UNION PAC.
MO. PAC.
M.K.& T.
FRISCO
TEX.& PAC.
COLO.& SOU.
D.& R.G.
SOU. PAC. SYS.
GRT. NOR.
1908
1909
1910
1911

FIG. 34

AVERAGE TRACTIVE FORCE OF LOCOMOTIVES—(POUNDS).

	1908	1909	1910	1911
N. Y. Central	29,188	30,344	30,523	31,554
Erie	27,845	27,964	28,687	28,893
N. Y. N. H. & H	22,643	22,714	22,777	22,856
Penn. R. R	31,401	31,887	32,073	32,509
D. & H	30,441	30,874	32,503	33,068
D. L. & W	25,739	26,035	26,877	27,571
C. R. R. of N. J	24,440	24,836	24,836	25,187
Lehigh Valley	26,992	27,151	27,752	28,091
Phil. & Read	26,557	26,568	26,734	27,872
Ches. & Ohio	31,356	32,095	32,771	32,266
At. Coast Line	20,202	20,235	20,322	20,564
Seab. Air Line	24,491	24,901	25,214	25,916
Southern	28,599	29,049	29,665	30,357
Lou. & Nash	26,404	26,563	27,220	28,092
Mob. & Ohio	26,288	26,289	26,387	25,909
Nash. C. & St. L	23,247	23,349	24,561	24,376
P. & L. E	32,627	33,452	35,163	35,761
L. E. & W	24,904	24,194	24,194	24,652

AVERAGE TRACTIVE FORCE OF LOCOMOTIVES—(POUNDS).

	1908	1909	1910	1911
P. C. C. & St. L	27,666	27,704	28,140	28,315
Vandalia	23,541	23,641	24,432	24,605
C. C. C. & St. L	28,088	29,251	30,577	31,905
Pere Marq	22,483	22,726	23,578	24,398
Mich. Central	23,924	24,425	26,568	28,340
Wabash	23,560	23,691	23,785	24,692
Ill. Central	24,487	24,492	24,801	25,263
C. & N. W	21,193	21,667	22,612	24,712
C. B. & Q	25,243	24,648	24,236	26,608
C. M. & St. P	20,510	20,488	21,418	22,415
Union Pac	30,070	30,041	30,585	30,773
Mo. Pac	27,941	29,808	28,022	29,173
M. K. & T	24,256	24,519	24,518	26,130
Frisco	24,501	25,009	25,709	27,067
Tex. & Pac	20,496	20,496	20,496	20,515
Colo. & Sou	28,057	28,368	28,352	29,335
D. & R. G	28,103	27,311	26,228	27,865
Sou. Pac. Sys	27,766	26,719	27,809	28,411
Great Nor	29,779	29,778	32,742	33,333

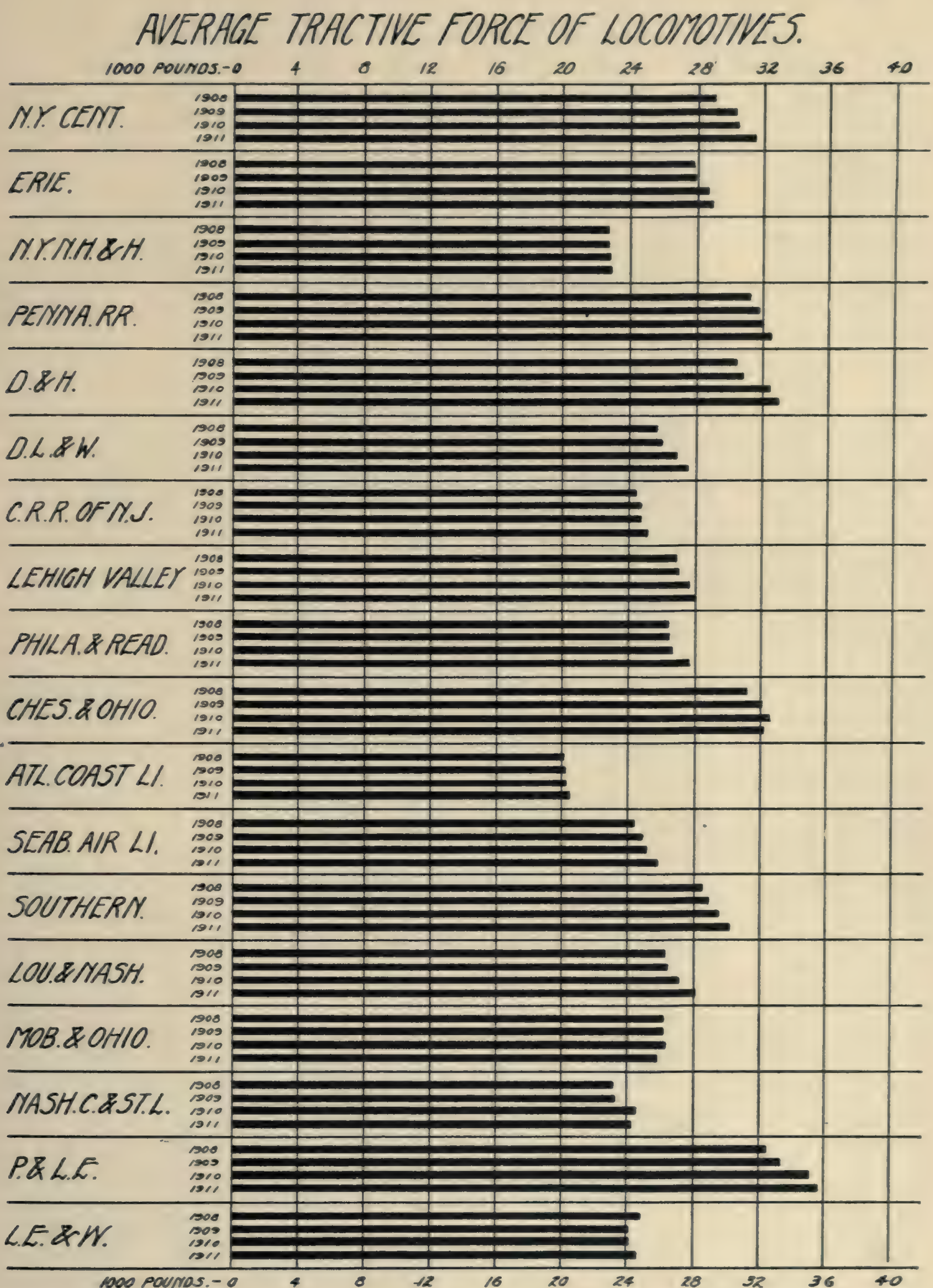

AVERAGE TRACTIVE FORCE OF LOCOMOTIVES.
1000 POUNDS.-0
4
8
12
16
20
24
28
32
36
40
N.Y. CENT.
ERIE.
N.Y.N.H.&H.
PENNA. RR.
D.&H.
D.L.&W.
C.R.R. OF N.J.
LEHIGH VALLEY
PHILA.& READ.
CHES.& OHIO.
ATL. COAST LI.
SEAB. AIR LI.
SOUTHERN.
LOU.& NASH.
MOB.& OHIO.
NASH.C.& ST.L.
P.& L.E.
L.E.& W.
1908
1909
1910
1911

FIG. 35

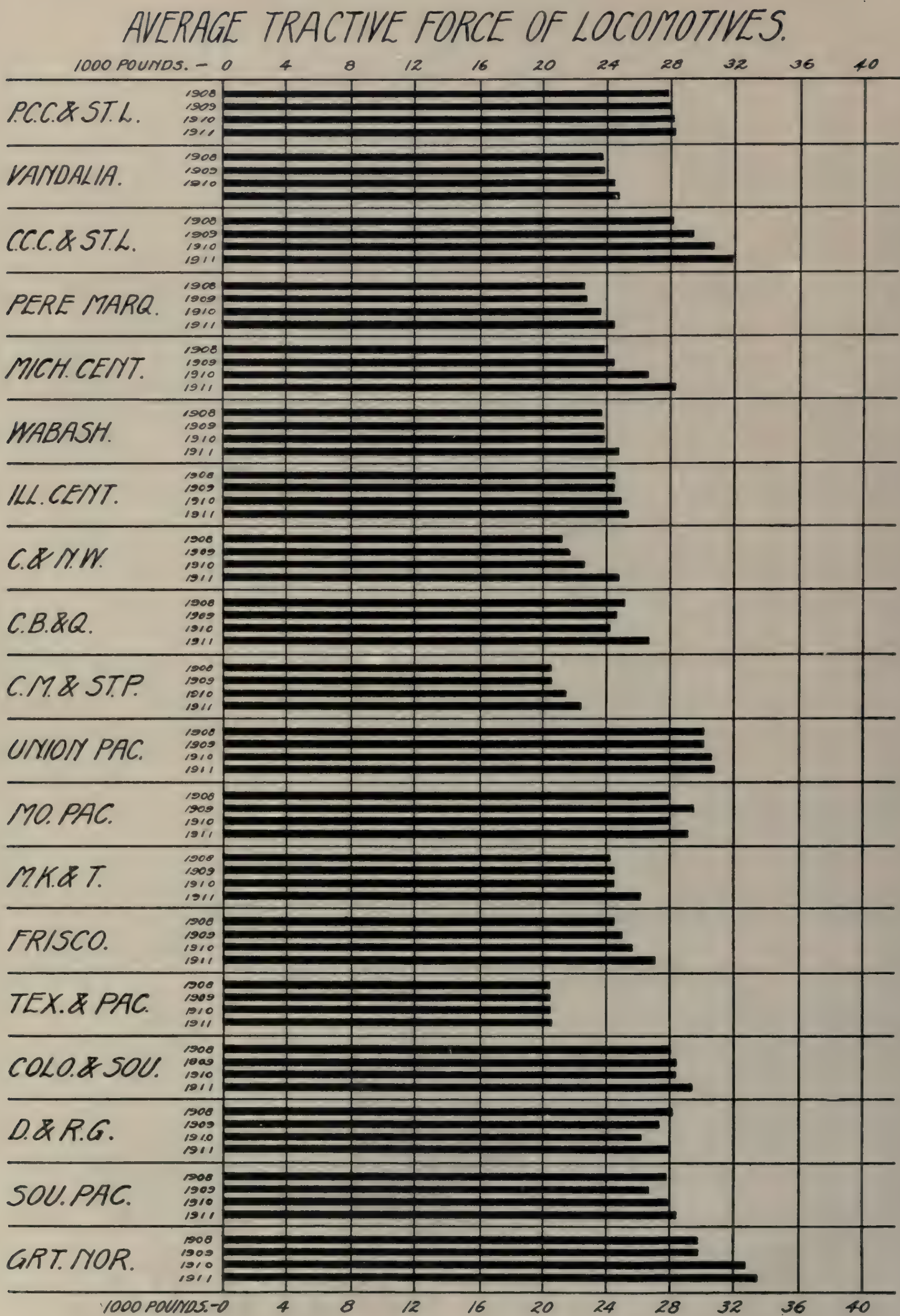

AVERAGE TRACTIVE FORCE OF LOCOMOTIVES.
1000 POUNDS. – 0 4 8 12 16 20 24 28 32 36 40
P.C.C.& ST.L.
VANDALIA.
C.C.C.& ST.L.
PERE MARQ.
MICH. CENT.
WABASH.
ILL. CENT.
C.& N.W.
C.B.&Q.
C.M.& ST.P.
UNION PAC.
MO. PAC.
M.K.& T.
FRISCO.
TEX.& PAC.
COLO.& SOU.
D.& R.G.
SOU. PAC.
GRT. NOR.
1908 1909 1910 1911
1000 POUNDS.–0 4 8 12 16 20 24 28 32 36 40

Fig. 36

MILES PER TOTAL LOCOMOTIVE.

	1908	1909	1910	1911
N. Y. Central	30,427	28,300	30,662	29,861
Erie	20,637	20,385	21,322	21,856
N. Y. N. H. & H.	25,206	24,200	24,293	24,845
Penn. R. R.	26,715	24,429	27,613	25,810
D. & H.	31,008	27,553	28,560	30,084
D. L. & W.	30,617	26,336	26,090	26,764
C. R. R. of N. J.	26,794	24,194	26,564	25,908
Lehigh Valley	24,392	22,786	25,064	25,084
Phil. & Read	24,662	23,354	25,384	24,817
Ches. & Ohio	25,427	25,128	28,048	26,516
At. Coast Line	28,972	27,792	30,107	30,584
Seab. Air Line	29,093	28,255	30,044	32,084
Southern	27,100	25,000	27,552	27,259
Lou. & Nash	36,300	34,800	37,901	38,080
Mob. & Ohio	29,615	29,065	29,781	32,043
Nash. C. & St. L.	36,886	35,647	37,030	36,858
P. & L. E.	22,606	23,364	28,512	25,283
L. E. & W.	25,541	25,341	28,430	29,329

MILES PER TOTAL LOCOMOTIVE.

	1908	1909	1910	1911
P. C. C. & St. L.	34,404	32,400	38,017	37,272
Vandalia	34,709	31,895	34,612	34,770
C. C. C. & St. L.	27,902	28,432	30,867	30,538
Pere Marq	24,648	25,070	26,510	30,167
Mich. Central	37,280	35,143	35,133	33,487
Wabash	32,586	29,822	31,895	33,753
Ill. Central	29,300	28,600	30,656	30,135
C. & N. W.	33,008	33,332	36,529	31,885
C. B. & Q.	26,800	26,800	30,904	28,739
C. M. & St. P.	35,873	37,012	39,490	36,947
Union Pac	29,950	28,500	32,297	29,574
Mo. Pac	29,500	30,700	31,988	31,269
M. K. & T.	29,614	29,841	32,929	29,931
Frisco	26,350	25,900	27,113	25,681
Tex. & Pac	26,146	25,382	26,543	26,493
Colo. & Sou	26,564	26,881	31,468	25,027
D. & R. G.	24,288	24,450	25,212	25,326
Sou. Pac. Sys	28,400	26,300	30,247	29,145
Great Nor	22,580	22,400	25,673	23,995

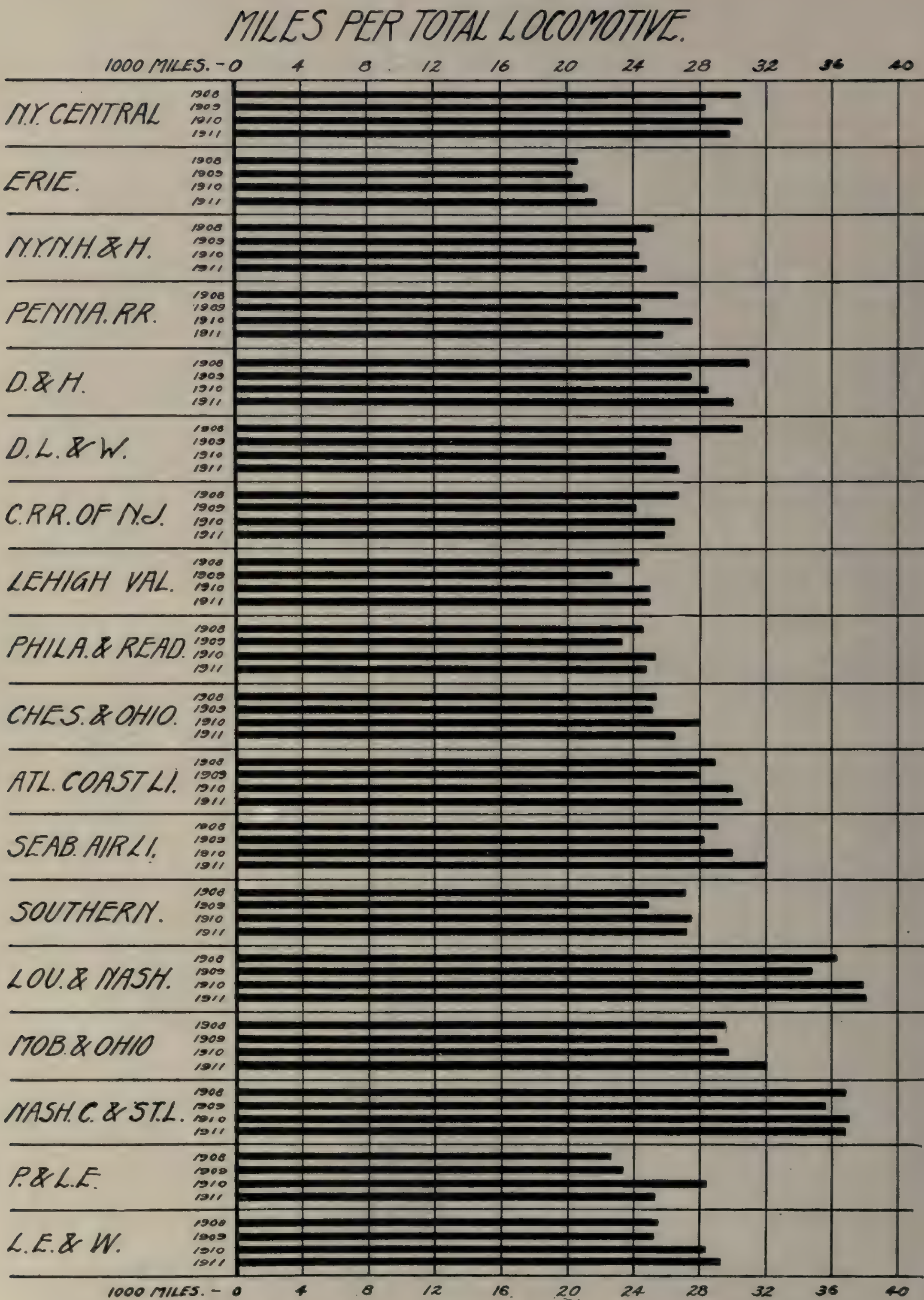

MILES PER TOTAL LOCOMOTIVE.
1000 MILES. - 0 4 8 12 16 20 24 28 32 36 40
N.Y. CENTRAL
ERIE.
N.Y.N.H. & H.
PENNA. RR.
D. & H.
D.L. & W.
C.RR. OF N.J.
LEHIGH VAL.
PHILA. & READ.
CHES. & OHIO.
ATL. COAST LI.
SEAB. AIR LI.
SOUTHERN.
LOU. & NASH.
MOB. & OHIO
NASH. C. & ST. L.
P. & L.E.
L.E. & W.
1908
1909
1910
1911

FIG. 37

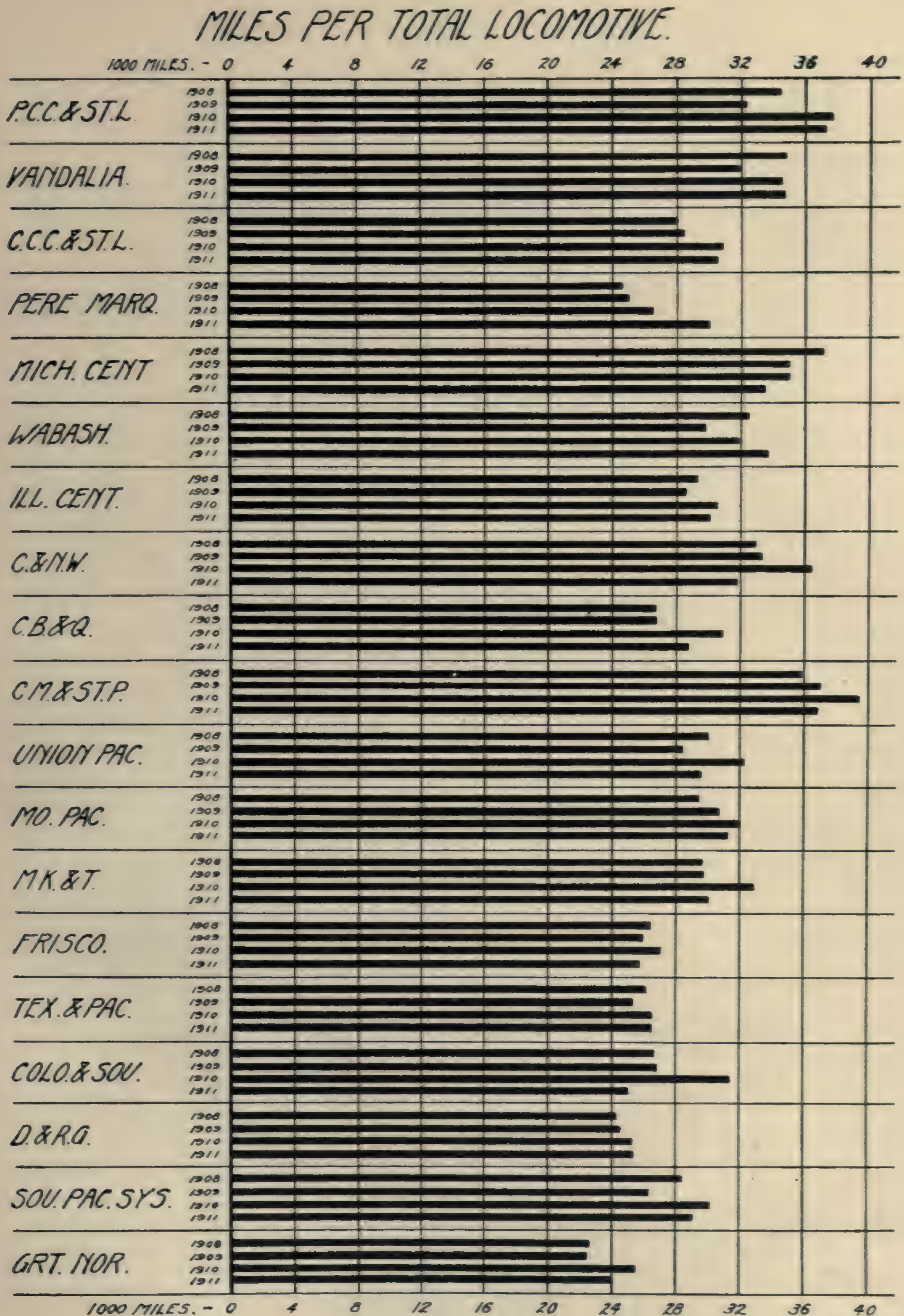

MILES PER TOTAL LOCOMOTIVE.
1000 MILES. - 0 4 8 12 16 20 24 28 32 36 40
P.C.C.&ST.L.
VANDALIA.
C.C.C.&ST.L.
PERE MARQ.
MICH. CENT
WABASH.
ILL. CENT.
C.&N.W.
C.B.&Q.
C.M.&ST.P.
UNION PAC.
MO. PAC.
M.K.&T.
FRISCO.
TEX.&PAC.
COLO.&SOU.
D.&R.G.
SOU.PAC.SYS.
GRT. NOR.
1908
1909
1910
1911
1000 MILES. - 0 4 8 12 16 20 24 28 32 36 40

FIG. 38

MAINTENANCE OF LOCOMOTIVES—PER LOCOMOTIVE MILE.

	1908	1909	1910	1911
N. Y. Central........	7.8 cents	7.5 cents	8.0 cents	8.5 cents
Erie	17.0	13.1	11.0	10.1
N. Y. N. H. & H......	7.2	7.2	7.0	8.4
Penn. R. R...........	10.3	10.2	10.0	11.1
D. & H...............	6.6	7.8	10.5	10.9
D. L. & W............	6.4	6.2	7.0	7.7
C. R. R. of N. J.......	8.5	9.1	8.5	8.7
Lehigh Valley.........	10.8	10.1	9.0	8.8
Phila. & Read........	10.9	10.1	11.0	11.2
Ches. & Ohio..........	8.0	9.1	8.8	9.4
At. Coast Lines.......	5.5	4.9	5.9	6.4
Seab. Air Line........	8.1	7.5	7.5	8.0
Southern	7.0	7.1	8.0	8.5
Lou. & Nash..........	8.9	8.1	8.0	8.4
Mob. & Ohio..........	4.9	6.0	6.8	7.6
Nash. C. & St. L......	6.0	6.0	6.3	6.6
P. & L. E............	6.2	6.4	5.8	8.3
L. E. & W............	12.4	12.0	10.2	11.0

MAINTENANCE OF LOCOMOTIVES—PER LOCOMOTIVE MILE.

	1908	1909	1910	1911
P. C. C. & St. L....	7.5 cents	7.9 cents	8.0 cents	8.7 cents
Vandalia	6.7	7.0	8.1	8.3
C. C. C. & St. L.......	8.0	8.2	9.1	9.0
Pere Marq............	7.3	7.3	6.7	7.7
Mich. Cent...........	5.4	6.5	6.4	7.0
Wabash	8.6	8.3	8.8	9.5
Ill. Central..........	8.3	9.3	10.0	10.5
C. & N. W............	5.4	5.8	6.0	7.1
C. B. & Q............	7.5	7.8	8.0	7.5
C. M. & St. P.........	5.4	5.4	6.0	7.1
Union Pac............	11.2	11.4	11.0	12.1
Mo. Pac..............	6.4	9.7	9.0	12.6
M. K. & T............	7.6	9.0	8.1	8.8
Frisco	7.7	9.2	11.0	9.5
Texas & Pac..........	7.9	8.9	8.8	11.9
Colo. & Sou..........	9.0	9.8	9.1	9.2
D. & R. G............	9.8	13.6	12.5	12.4
Sou. Pac. Sys.........	10.8	12.5	12.0	12.0
Great Nor............	9.1	7.9	9.0	9.5

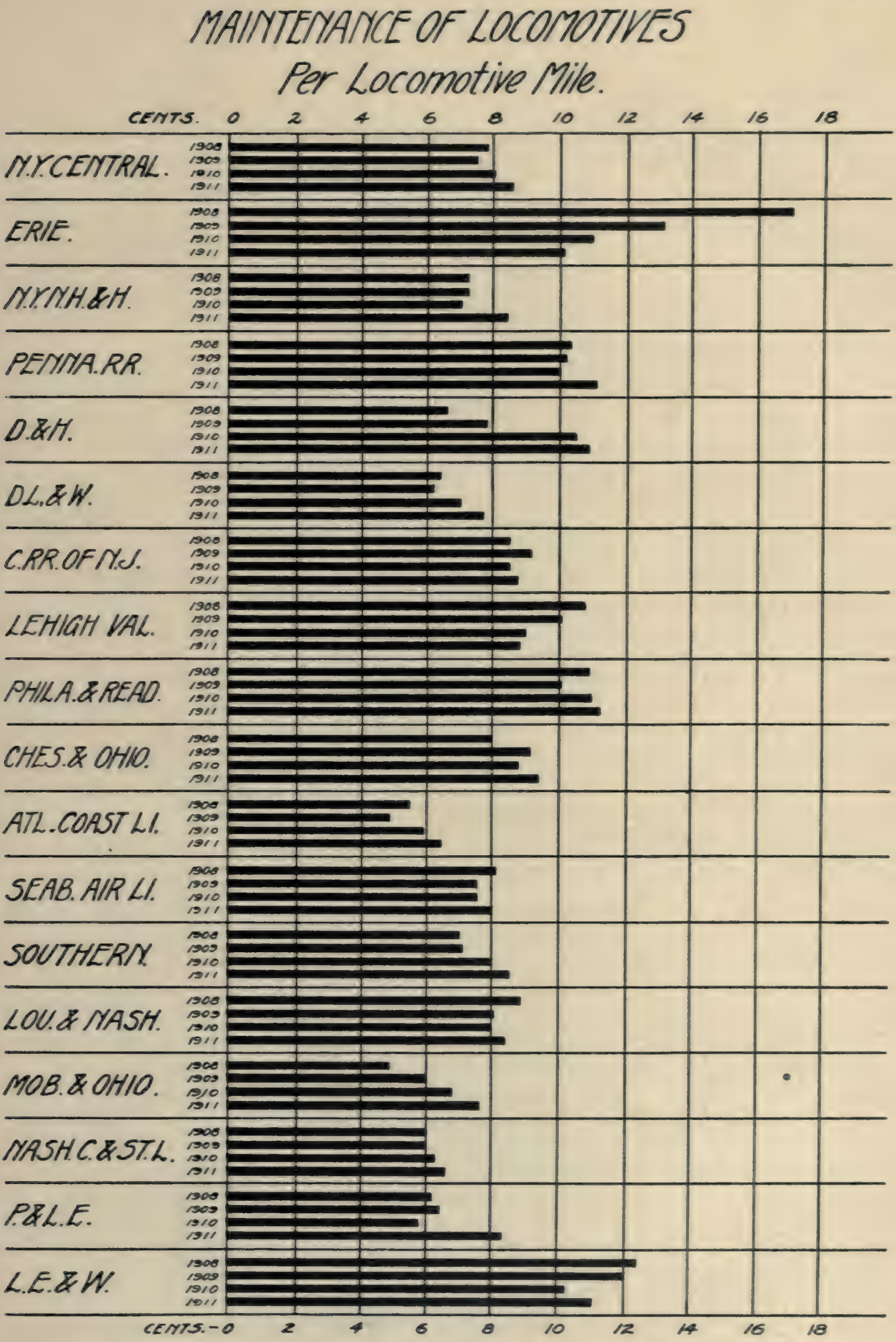

MAINTENANCE OF LOCOMOTIVES
Per Locomotive Mile.
CENTS. 0 2 4 6 8 10 12 14 16 18
N.Y. CENTRAL.
ERIE.
N.Y.N.H.&H.
PENNA.RR.
D.&H.
D.L.&W.
C.RR.OF N.J.
LEHIGH VAL.
PHILA.&READ.
CHES.& OHIO.
ATL.COAST LI.
SEAB. AIR LI.
SOUTHERN.
LOU.& NASH.
MOB.& OHIO.
NASH.C.&ST.L.
P.&L.E.
L.E.&W.
1908
1909
1910
1911
CENTS.-0 2 4 6 8 10 12 14 16 18

Fig. 39

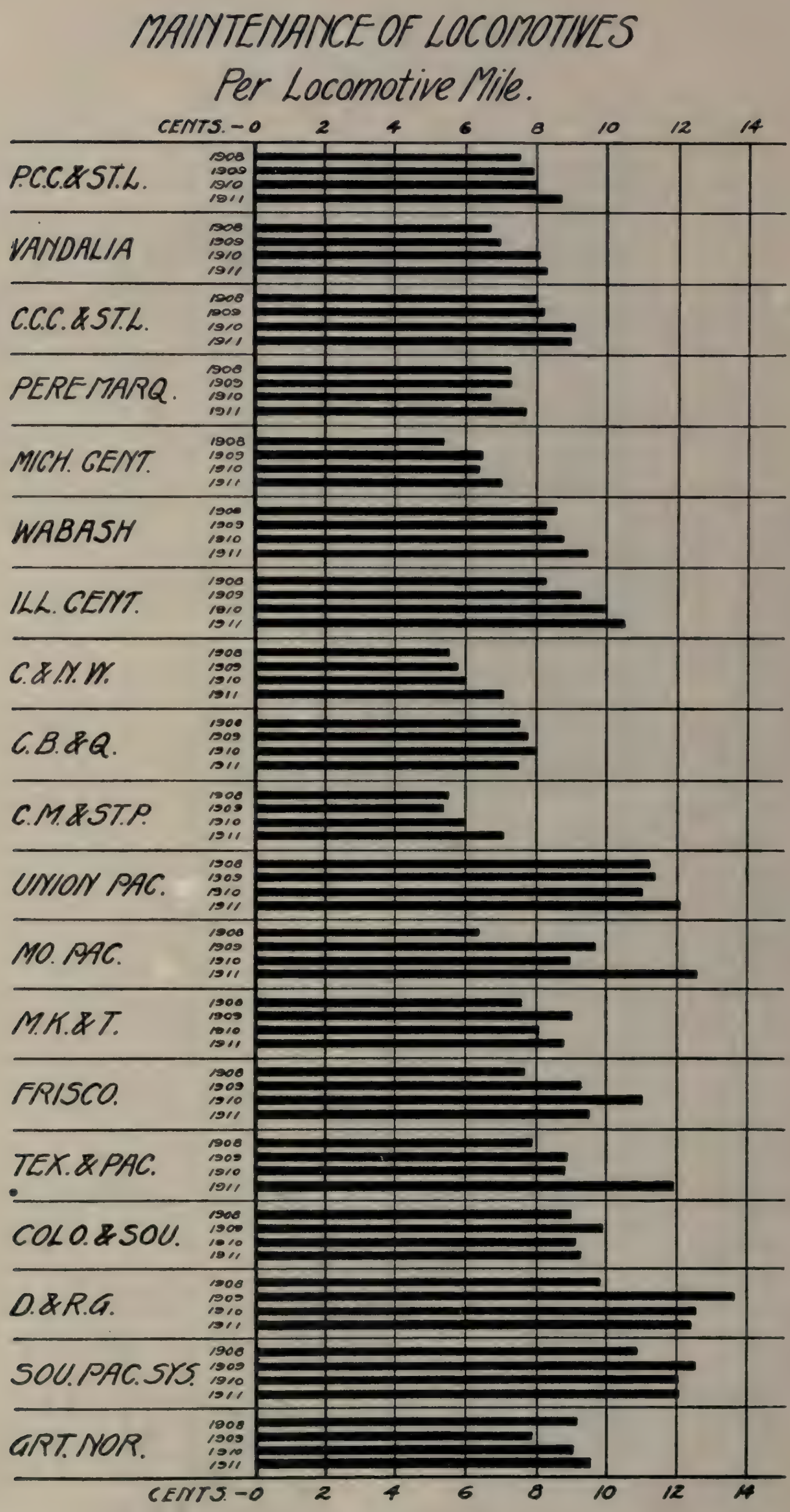

MAINTENANCE OF LOCOMOTIVES
Per Locomotive Mile.
CENTS. – 0 2 4 6 8 10 12 14
P.C.C.&ST.L.
VANDALIA
C.C.C.&ST.L.
PERE MARQ.
MICH. CENT.
WABASH
ILL. CENT.
C.&N.W.
C.B.&Q.
C.M.&ST.P.
UNION PAC.
MO. PAC.
M.K.&T.
FRISCO.
TEX.&PAC.
COLO.&SOU.
D.&R.G.
SOU.PAC.SYS.
GRT.NOR.
1908
1909
1910
1911
CENTS. – 0 2 4 6 8 10 12 14

FIG. 40

Maintenance of Locomotives—Per Tractive Mile.

	1908	1909	1910	1911
N. Y. Central	$2.69	$2.47	$2.51	$2.72
Erie	6.13	4.70	3.67	3.50
N. Y. N. H. & H.	3.17	2.80	3.27	3.71
Penn. R. R.	3.29	3.21	3.13	3.42
D. & H.	2.16	2.52	3.23	3.30
D. L. & W.	2.49	2.39	2.51	2.80
C. R. R. of N. J.	3.46	3.71	3.44	3.45
Lehigh Valley	4.02	3.72	3.24	3.14
Phila. & Read	4.13	3.80	4.03	4.03
C. & O.	2.54	2.82	2.68	2.92
Atl. Coast Line	2.73	2.43	2.91	3.13
Seab. Air Line	3.30	3.00	2.97	3.07
Southern	2.46	2.43	2.83	2.83
Lou. & Nash	3.39	3.04	2.88	3.02
Mob. & Ohio	1.87	2.30	2.60	2.94
Nash. C. & St. L.	2.56	2.55	2.57	2.72
P. & L. E.	1.91	1.93	1.65	2.31
L. E. & W.	4.96	4.97	4.20	4.47

Maintenance of Locomotives—Per Tractive Mile.

	1908	1909	1910	1911
P. C. C. & St. L.	$2.72	$2.87	$2.76	$3.09
Vandalia	2.85	2.96	3.30	3.37
C. C. C. & St. L.	2.84	2.79	2.96	2.82
Pere Marq	3.23	3.22	2.85	3.15
Mich. Cent.	2.25	2.66	2.39	2.47
Wabash	3.58	3.48	3.71	3.84
Ill. Central	3.39	3.80	4.06	4.17
C & N. W.	2.57	2.66	2.78	2.87
C. B. & Q.	2.99	3.18	3.16	2.83
C. M. & St. P.	2.65	2.64	2.79	3.17
Union Pac.	3.68	3.78	3.73	3.96
Mo. Pac.	2.31	3.24	3.19	4.35
M. K. & T.	3.12	3.67	3.32	3.37
Frisco	3.16	3.71	4.17	3.52
Texas & Pac.	3.84	4.33	4.29	5.82
Colo. & Sou.	3.22	3.49	3.22	3.16
D. & R. G.	3.48	4.96	4.77	4.47
Sou. Pac. Sys.	4.12	4.53	4.40	4.23
Great Nor.	3.08	2.67	2.65	2.85

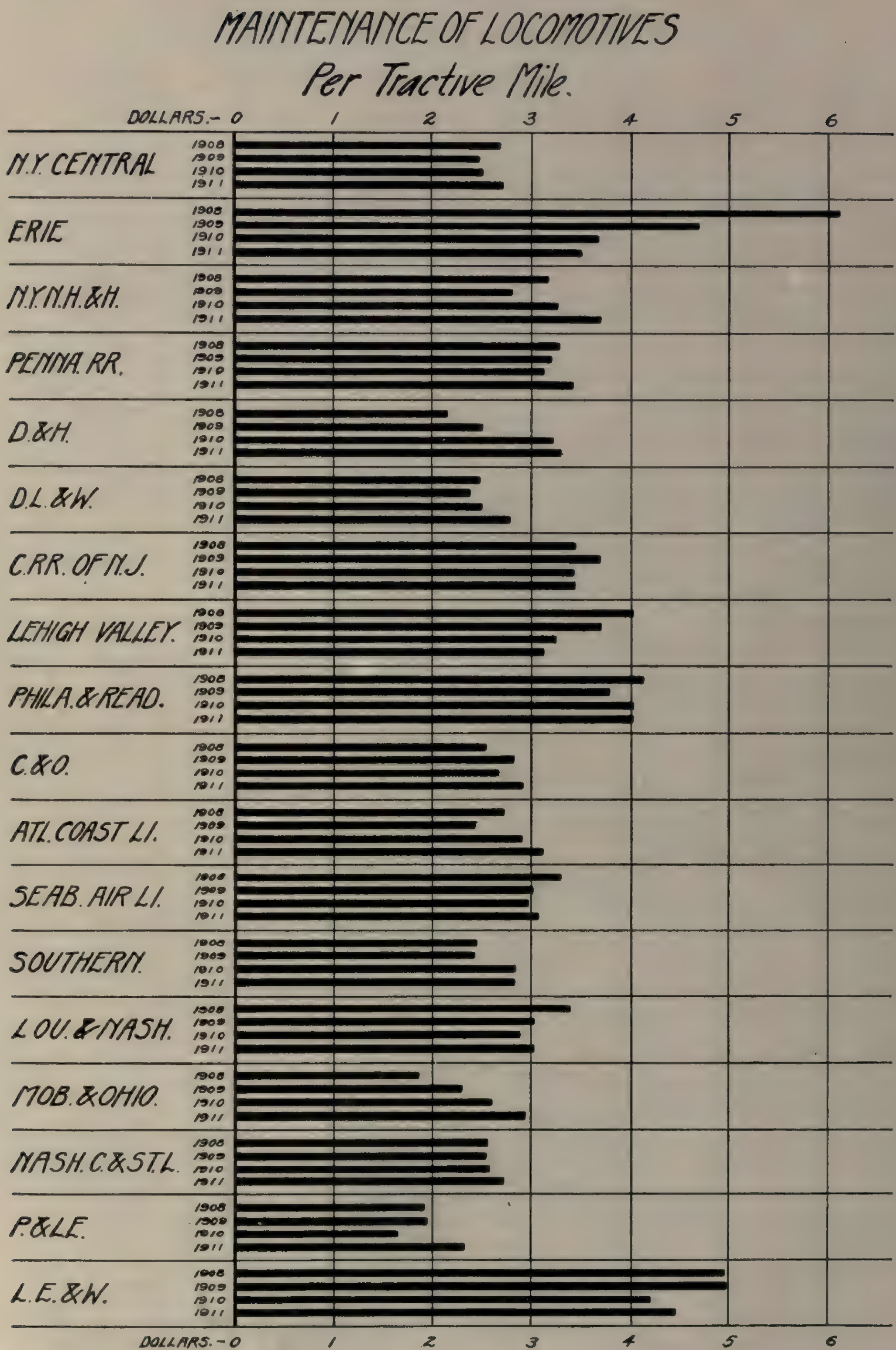

MAINTENANCE OF LOCOMOTIVES
Per Tractive Mile.
DOLLARS.- 0
1
2
3
4
5
6
N.Y. CENTRAL
ERIE
N.Y.N.H.&H.
PENNA. RR.
D.&H.
D.L.&W.
C.RR. OF N.J.
LEHIGH VALLEY.
PHILA.&READ.
C.&O.
ATL. COAST LI.
SEAB. AIR LI.
SOUTHERN.
LOU.&NASH.
MOB.&OHIO.
NASH.C.&ST.L.
P.&L.E.
L.E.&W.
1908
1909
1910
1911

FIG. 41

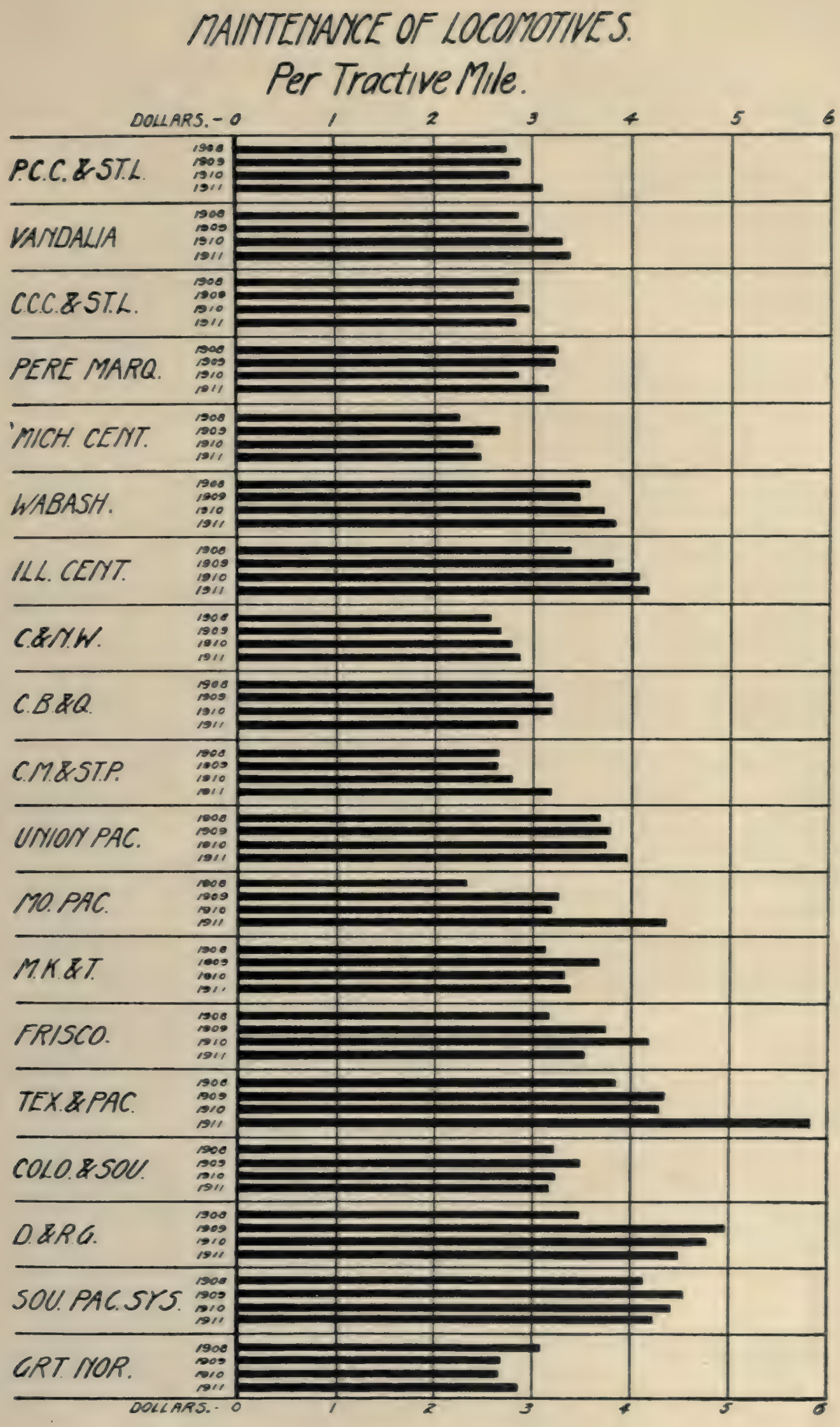

MAINTENANCE OF LOCOMOTIVES.
Per Tractive Mile.
DOLLARS.- 0 1 2 3 4 5 6
P.C.C. & ST.L.
VANDALIA
C.C.C. & ST.L.
PERE MARQ.
MICH. CENT.
WABASH.
ILL. CENT.
C.&N.W.
C.B.&Q.
C.M.&ST.P.
UNION PAC.
MO. PAC.
M.K.&T.
FRISCO.
TEX.& PAC.
COLO.& SOU.
D.&R.G.
SOU. PAC. SYS.
GRT. NOR.
1908
1909
1910
1911
DOLLARS.- 0 1 2 3 4 5 6

FIG. 42

The following data taken from these tables serves to further emphasize how erroneous conclusions may be reached in employing either the "locomotive" or the "locomotive mile" in place of "tractive mile" as the comparative unit.

Maintenance of Locomotives

1911

	Per Locomotive	Per Locomotive Mile	Per Tractive Mile
Penn R. R.	$2,865	11.1 cents	$3.42
New Haven	2,107	8.4	3.71
N. Y. Central	$2,559	8.5 cents	$2.72
C. R. R. of N. J.	2,254	8.7	3.45
Del. & Hud.	$3,283	10.9 cents	$3.30
Erie	2,210	10.1	3.50

Locomotive maintenance on the Pennsylvania R. R. in 1911 shows an *increase* of 35 per cent. "per locomotive" over the New Haven, an *increase* of 32 per cent. "per locomotive mile" and a *decrease* of *8 per cent.* "per tractive mile."

The New York Central shows an *increase* of *13 per cent.* "per locomotive" as compared with the Central R. R. of New Jersey, a *decrease* of *2 per cent.* "per locomotive mile" and a *decrease* of *21 per cent.* "per tractive mile."

Maintenance costs on the Erie were *33 per cent. less* "per locomotive" than the Delaware & Hudson, *7 per cent. less* "per locomotive mile," but were *6 per cent. more* "per tractive mile."

Maintenance of Locomotives

1911

	Per Locomotive	Per Locomotive Mile	Per Tractive Mile
Southern Ry.	$2,551	8.5 cents	$2.83
Atl. Coast Line	1,970	6.4	3.13
Lou. & Nash.	$3,228	8.4 cents	$3.02
Ill. Central	3,175	10.5	4.17
Union Pac.	$3,604	12.1 cents	$3.96
Burlington	2,164	7.5	2.83

Locomotive maintenance costs in 1911 on the Southern were *29 per cent. higher* "per locomotive" than on the Atlantic Coast Line, *33 per cent. higher* "per locomotive mile" and *9.5 per cent. lower* "per tractive mile."

The Louisville & Nashville costs show a 1.5 per cent. *increase* "per locomotive" when compared with the Illinois Central, 20 per cent. *decrease* "per locomotive mile" and 27.5 per cent. *decrease* "per tractive mile."

The Union Pacific with maintenance costs "per locomotive" and "per locomotive mile" *61 per cent. higher* than the Burlington are only *40 per cent. higher* than the latter "per tractive mile."

MAINTENANCE OF LOCOMOTIVES

1911

	Per Locomotive	Per Locomotive Mile	Per Tractive Mile
M. K. & T.	$2,633	8.8 cents	$3.37
Frisco	2,448	9.5	3.52
Tex. & Pac.	$3,165	11.9 cents	$5.82
D. & R. G.	3,151	12.4	4.47
Sou. Pac.	$3,499	12.0 cents	$4.23
Great Nor.	2,280	9.5	2.85

On the M. K. & T. in 1911 locomotive maintenance costs show an *increase* of *7 per cent.* "per locomotive" as compared with the Frisco, a *decrease* of *7 per cent.* "per locomotive mile" and a *decrease* of *4.3 per cent.* per tractive mile.

The Texas & Pacific, with maintenance costs "per locomotive" less than *1 per cent. higher* than the Denver & Rio Grande, shows *4 per cent. less* "per locomotive mile" and *30 per cent. more* "per tractive mile."

Comparing the Southern Pacific with the Great Northern locomotive maintenance costs on the former road show an *increase* of *53 per cent.* "per locomotive," an *increase of 26 per cent.* "per locomotive mile" and an increase of 48 per cent. "per tractive mile."

These studies cannot, however, be carried to a definite conclusion, due to the absence of the necessary data in the records of the Interstate Commerce Commission. For a thorough analysis of locomotive maintenance costs should be separated among freight, passenger and switch service. The miles in each class of service should also be separated.

The information on file in these records should also be sufficiently subdivided as to enable the maintenance costs to be more satisfactorily determined as between compound and single expansion locomotives.

Railroads operating in a thickly settled country have access to a well-supplied labor market and, in consequence, the wages are considerably lower than railroads operating in a sparsely settled country where labor is scarce. Since labor constitutes 60 per cent. of the maintenance costs, these variations in the rate of wages will have a substantial influence on the total maintenance costs, particularly between eastern and western roads. While there is not the same variation in costs of material as those for labor, there is considerable difference in the costs to railroads operating in the manufacturing locality as compared with those roads which do not touch the manufacturing centers.

In reporting their maintenance costs to the Interstate Commerce Commission, labor and material costs should be segregated to permit the situation to be thoroughly analyzed.

Sufficient data should also be available to accurately determine the effect of grades and other operating conditions upon the maintenance costs.

Passenger Car Maintenance

CHAPTER VI.

Passenger car maintenance in 1911 was approximately 8 per cent. of the total expenditure for maintenance of equipment or about 2 per cent. of the total operating expense, and is therefore of relative minor importance when considered with the maintenance of locomotives or freight cars.

As with freight car maintenance, the usual method of comparison is on the basis "per car owned," and the accompanying chart, Fig. 43, shows the maintenance cost on this basis during 1911 for a number of representative roads. The extremes in this table are $317 on the Central Railroad of New Jersey and $1,056 on the Louisville & Nashville, a difference of 233 per cent.

If the cost per passenger car is the proper basis for comparison from these figures, it is evident that passenger car maintenance on the L. & N. is more than three times what it should be.

MAINTENANCE OF PASSENGER CARS PER PASSENGER CAR.

1911.

N. Y. N. H. & H.	$405.73	Penna Co.	$646.64
B. & M.	479.48	N. Y. C. & St. L.	785.33
N. Y. Central	759.65	Mich. Central	586.70
Penn. R. R.	820.86	Pere Marq	635.62
D. & H.	430.48	P. C. C. & St. L.	815.40
D. L. & W.	650.47	Vandalia	1,038.21
Lehigh Valley	483.91	C. C. C. & St. L.	735.84
P. & R.	853.14	Wabash	782.15
C. R. R. of N. J.	317.10	C. & A.	923.17
Erie	479.50	M. St. P. & S. S. M.	902.14
B. & O.	685.17	C. G. W.	868.22
N. & W.	778.92	Ill. Central	890.97
C. & O.	788.07	C. B. & Q.	571.54
A. C. L.	812.60	C. & N. W.	495.23
S. A. L.	801.50	C. R. I. & P.	843.55
Sou. Ry.	673.56	Union Pac.	998.79
L. & N.	1,056.31	Santa Fe Sys.	936.33
M. & O.	705.86	Sou. Pac. Sys.	884.66
Nash. C. & St. L.	804.55	Nor. Pac.	511.70
L. S. & M. S.	978.95	Grt. Nor.	587.67

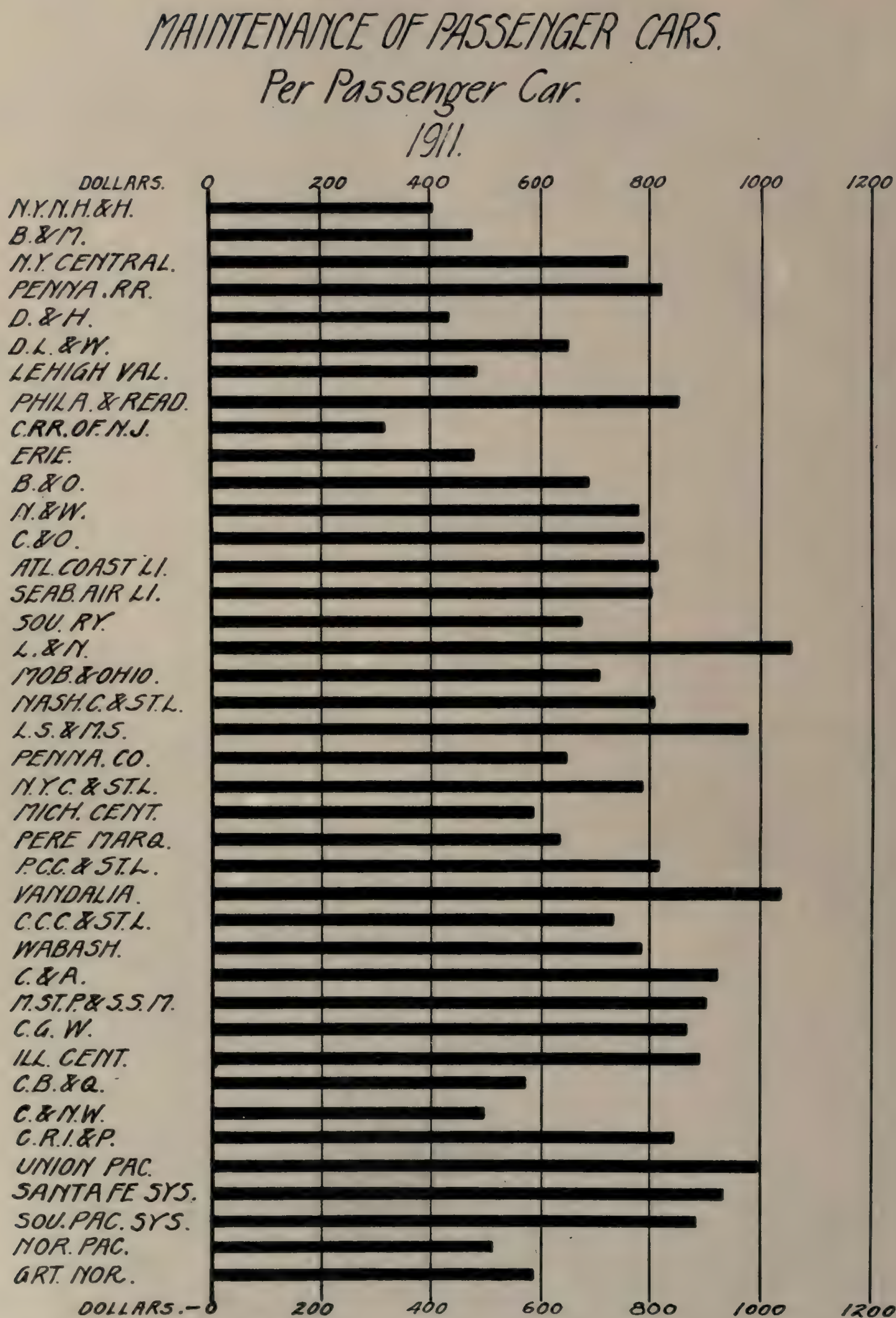

MAINTENANCE OF PASSENGER CARS.
Per Passenger Car.
1911.
DOLLARS.
0
200
400
600
800
1000
1200
N.Y.N.H.&H.
B.&M.
N.Y. CENTRAL.
PENNA. RR.
D.&H.
D.L.&W.
LEHIGH VAL.
PHILA.&READ.
C.RR. OF N.J.
ERIE.
B.&O.
N.&W.
C.&O.
ATL. COAST LI.
SEAB. AIR LI.
SOU. RY.
L.&N.
MOB.&OHIO.
NASH.C.&ST.L.
L.S.&M.S.
PENNA. CO.
N.Y.C.&ST.L.
MICH. CENT.
PERE MARQ.
P.C.C.&ST.L.
VANDALIA.
C.C.C.&ST.L.
WABASH.
C.&A.
M.ST.P.&S.S.M.
C.G.W.
ILL. CENT.
C.B.&Q.
C.&N.W.
C.R.I.&P.
UNION PAC.
SANTA FE SYS.
SOU. PAC. SYS.
NOR. PAC.
GRT. NOR.
DOLLARS.—0
200
400
600
800
1000
1200

Fig. 43

Of similar comparison is the performance on two railroads operating in the same general territory, the Illinois Central with an average of $891 per car and the Burlington with an average cost of $571 per car. With the car unit and the Burlington cost as a standard, the Illinois Central should reduce their passenger car maintenance costs 36 per cent.

The same factors, however, which serve to modify the value of the car as a comparative unit in freight car maintenance are similarly influential in affecting its value in passenger car maintenance, viz., number of cars owned and the average mileage. The size, design and material of construction will also affect the average maintenance cost per car.

With the same design, size and class of passenger car the maintenance should vary with the average miles run, and the accompanying table and chart, Fig. 44, show the average mileage in 1911 per passenger car owned on the same railroad as those illustrated in Fig. 43.

In this comparative table the poorest performance is the Central Railroad of New Jersey, with 27,519 miles, and the best record is the Union Pacific, with 126,698 miles, a variation of 360 per cent.

With further reference to the comparison of the Central Railroad of New Jersey with the L. & N., the data just quoted indicates the necessity of carrying the study for further consideration. The average miles run of passenger cars on the former road was 27,519 miles and on the latter road 85,209 miles, a difference of 210 per cent.

MILES PER PASSENGER CAR OWNED.

1911.

	Miles		Miles
N. Y. N. H. & H.	30,104	Penn. Co.	80,291
B. & M.	31,368	N. Y. C. & St. L.	93,608
N. Y. Central	64,405	Mich. Central	90,988
Penn. R. R.	62,810	Pere Marq	44,696
D. & H.	31,618	P. C. C. & St. L.	88,663
D. L. & W.	43,846	Vandalia	86,497
Leh. Valley	45,339	C. C. C. & St. L.	85,936
P. & R.	33,996	Wabash	89,640
C. R. R. of N. J.	27,519	C. & A.	90,157
Erie	46,457	M. St. P. & S. S. M.	83,116
B. & O.	71,391	C. G. W.	76,553
N. & W.	55,137	Ill. Central	78,940
C. & O.	67,628	C. B. & Q.	87,206
A. C. L.	72,940	C. & N. W.	58,829
S. A. L.	80,089	C. R. I. & P.	89,538
Sou. Ry.	75,374	Union Pac.	126,698
L. & N.	85,209	Santa Fe Sys.	89,662
M. & O.	67,723	Sou. Pac. Sys.	77,525
Nash. C. & St. L.	60,818	Nor. Pac.	62,313
L. S. & M. S.	97,528	Grt. Nor.	69,770

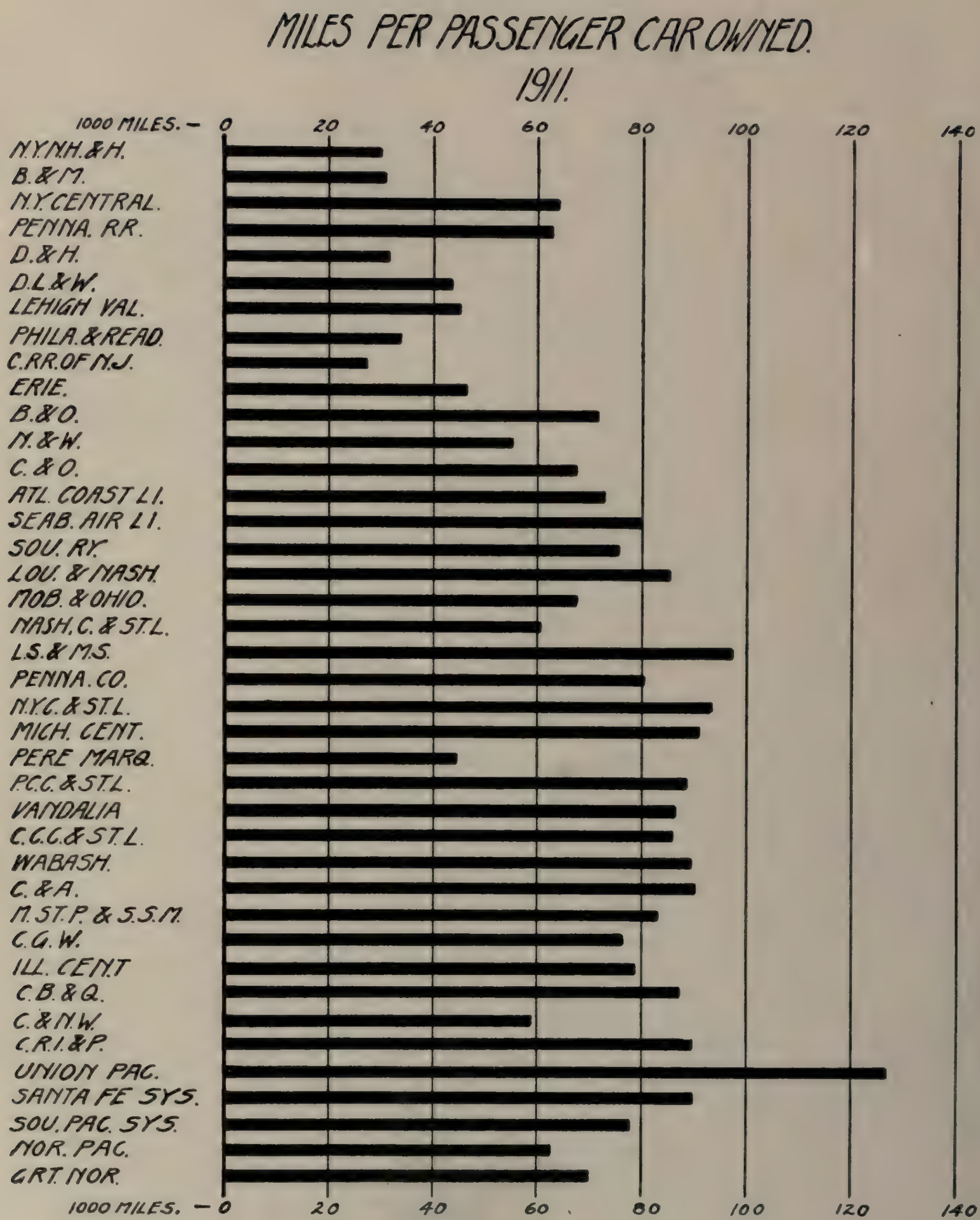

MILES PER PASSENGER CAR OWNED.
1911.
1000 MILES. – 0 20 40 60 80 100 120 140
N.Y.N.H.&H.
B.&M.
N.Y.CENTRAL.
PENNA. RR.
D.&H.
D.L.&W.
LEHIGH VAL.
PHILA.&READ.
C.RR.OF N.J.
ERIE.
B.&O.
N.&W.
C.&O.
ATL. COAST LI.
SEAB. AIR LI.
SOU. RY.
LOU. & NASH.
MOB. & OHIO.
NASH.C.&ST.L.
L.S.&M.S.
PENNA.CO.
N.Y.C.&ST.L.
MICH. CENT.
PERE MARQ.
P.C.C.&ST.L.
VANDALIA
C.C.C.&ST.L.
WABASH.
C.&A.
M.ST.P.&S.S.M.
C.G.W.
ILL. CENT
C.B.&Q.
C.&N.W.
C.R.I.&P.
UNION PAC.
SANTA FE SYS.
SOU.PAC.SYS.
NOR.PAC.
GRT.NOR.
1000 MILES. – 0 20 40 60 80 100 120 140

Fig. 44

If the passenger cars on the C. R. R. of N. J. had averaged the same mileage as on the L. & N., the number of cars on the former road would have been reduced from 642 to 206, resulting in an increase in the average maintenance cost per car for the year 1911 from $317 to $988, an increase of 212 per cent.

The figures thus obtained show a variation in maintenance cost "per passenger car" of less than 7 per cent. on these two railroads, as compared with the variation of 233 per cent. previously quoted.

On the Burlington the average miles per passenger car was 87,209 miles as compared with 78,940 miles on the Illinois Central, a difference of 8,269 miles, or 9.5 per cent.

If the passenger cars on the Illinois Central had averaged the same mileage as the Burlington, the number of cars required would have been reduced from 887 to 803, or sufficiently to raise the cost per car from $891 to $984.

Comparisons of this nature could be carried on extensively and the results are interesting, but have little value. They merely serve to demonstrate the futility of making any use of the passenger car unit in comparing the performance of different railroads.

The same may be said of this unit in comparing the performance on the same railroad for different periods. For example, the C. & N. W. maintenance costs were $562 per passenger car in 1910 and $495 per car in 1911, a reduction of 12 per cent.

In 1910 this road reported a total of 1,452 passenger cars and 1,712 cars in 1911, an increase of 17.8 per cent., while the average mileage per passenger car de-

Maintenance of Passenger Cars per 1,000 Passenger Car Miles.

1911.

N. Y. N. H. & H.	$13.48	Penna. Co.	$8.05
B. & M.	15.29	N. Y. C. & St. L.	8.38
N. Y. Central	11.79	Mich. Central	6.45
Penn. R. R.	13.07	Pere Marq.	14.22
D. & H.	13.62	P. C. C. & St. L.	9.20
D. L. & W.	14.84	Vandalia	12.00
Leh. Valley	10.67	C. C. C. & St. L.	8.56
P. & R.	25.09	Wabash	8.73
C. R. R. of N. J.	11.52	C. & A.	10.24
Erie	10.32	M. St. P. & S. S. M.	10.85
B. & O.	9.60	C. G. W.	11.34
N. & W.	14.13	Ill. Central	11.29
C. & O.	11.65	C. B. & Q.	6.55
Atl. Coast Line	11.14	C. & N. W.	8.42
S. A. L.	10.01	C. R. I. & P.	9.42
Sou. Ry.	8.94	Union Pac.	7.88
L. & N.	12.40	Santa Fe Sys.	10.44
M. & O.	10.42	Sou. Pac. Sys.	11.41
Nash. C. & St. L.	13.23	Nor. Pac.	8.21
L. S. & M. S.	10.04	Grt. Nor.	8.42

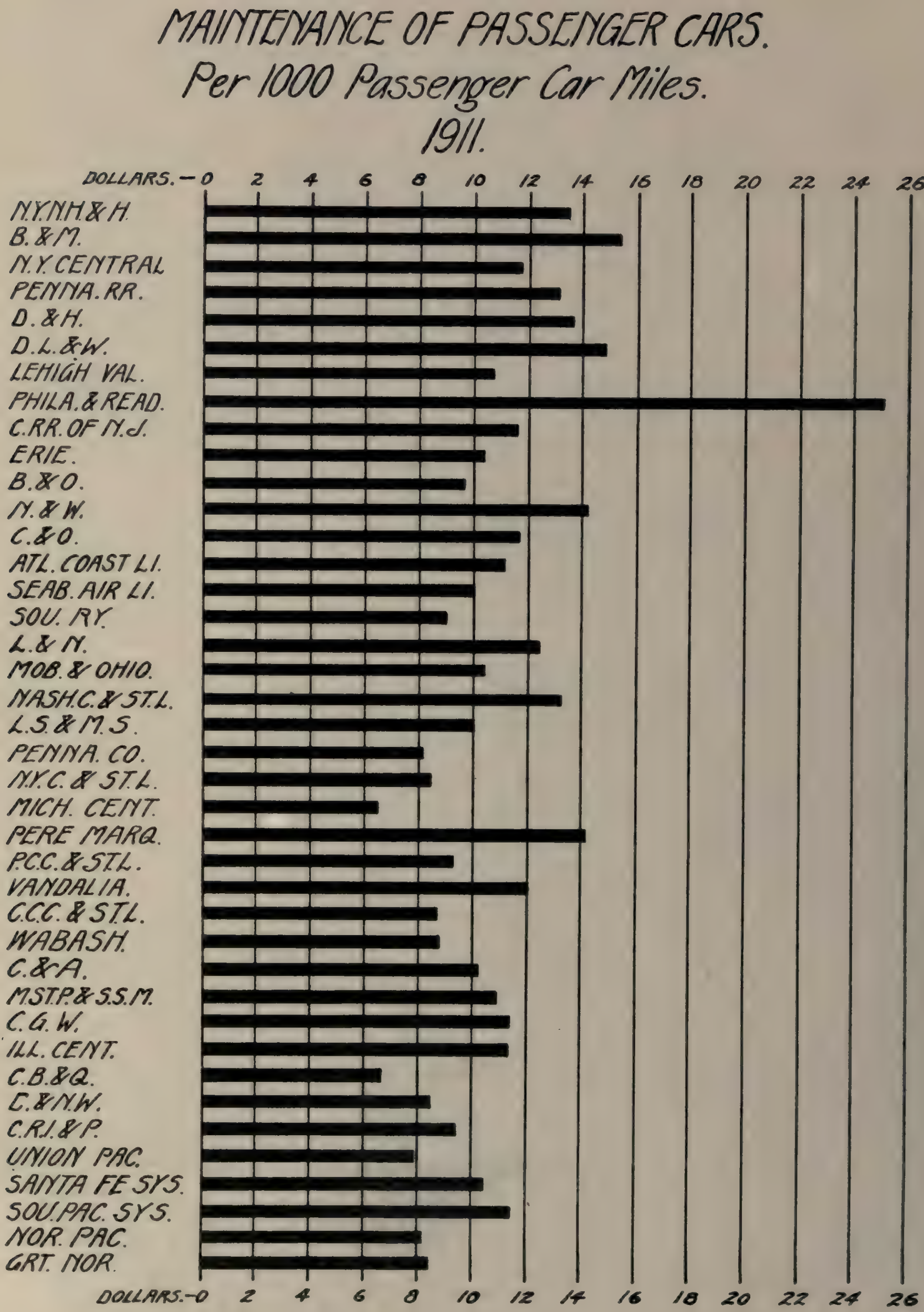

MAINTENANCE OF PASSENGER CARS.
Per 1000 Passenger Car Miles.
1911.
DOLLARS.—0 2 4 6 8 10 12 14 16 18 20 22 24 26
N.Y.N.H.&H.
B.&M.
N.Y.CENTRAL
PENNA.RR.
D.&H.
D.L.&W.
LEHIGH VAL.
PHILA.&READ.
C.RR.OF N.J.
ERIE.
B.&O.
N.&W.
C.&O.
ATL.COAST LI.
SEAB.AIR LI.
SOU. RY.
L.& N.
MOB.& OHIO.
NASH.C.&ST.L.
L.S.&M.S.
PENNA. CO.
N.Y.C.& ST.L.
MICH. CENT.
PERE MARQ.
P.C.C.&ST.L.
VANDALIA.
C.C.C.&ST.L.
WABASH.
C.&A.
M.ST.P.&S.S.M.
C.G.W.
ILL. CENT.
C.B.&Q.
C.&N.W.
C.R.I.&P.
UNION PAC.
SANTA FE SYS.
SOU.PAC. SYS.
NOR. PAC.
GRT. NOR.
DOLLARS.—0 2 4 6 8 10 12 14 16 18 20 22 24 26

FIG. 45

creased 11.7 per cent. in 1911 as compared with 1910. The reduction in the average maintenance cost per car was entirely due to the increase in the number of cars owned rather than to any improvement in performance, as the average cost per 1,000 miles run increased from $8.36 in 1910 to $8.42 in 1911.

Further similar comparisons can be made among the different railroads, but as has been mentioned above, the resulting figures are of but little practical value.

Passenger car maintenance costs are in direct relation to the weight and the distance carried. The gross ton mile is therefore the most satisfactory unit as in the case of freight cars, but this figure is not reported to the Interstate Commerce Commission. Many railroads do not maintain any record of gross ton mileage in passenger service.

The only data available for any comparison of passenger car maintenance is on the basis of miles run, and the accompanying table shows the average costs per 1,000 car miles in 1911, which are illustrated in Fig. 45.

The extremes are the Michigan Central with an average cost of $6.45 per 1,000 car miles and the Reading with $25.09 per 1,000 miles, a variation of 289 per cent.

It is interesting to continue the study of the railroads mentioned above.

	Maintenance Per Car	Average Miles Run	Maintenance Per 1000 Miles
C. R. R. of N. J.	$317.00	27.519	$11.52
Lou. & Nash	1,056.00	85.209	12.40
Ill. Central	$891.00	78.940	$11.29
Burlington	571.00	87.206	6.55

The Central Railroad of New Jersey had an average cost of $11.52 per 1,000 car miles and the Louisville & Nashville an average of $12.40, an entirely different aspect from the comparison on the car unit basis. The same is true of the Illinois Central with an average cost of $11.29 per 1,000 miles and the Burlington with $6.55 per 1,000 miles.

These conclusions cannot be considered as final since the size and construction of equipment, operating characteristics and the demands of the traveling public all have bearing on the repair costs, and comparisons among different roads with full knowledge of all conditions are of doubtful value.

Unfortunately, the Interstate Commerce Commission records do not contain any data with reference to the size, material of construction, capacity or weight of the passenger cars of any of the railroads. As cars 70 feet in length with six-wheel trucks will cost more to maintain than cars 55 feet in length with four-wheel trucks it is impractical to continue the present study in the absence of this data.

Data should also be on file showing the number and size of cars of all steel construction, wooden cars with steel underframes, wooden cars with steel reinforcement and all wooden cars, together with the total mileage made by the cars of each type to permit of more conclusive analytical studies.

The demands of the traveling public and the fluctuations in volume of both local and through traffic influence the number of passenger cars owned by any railroad, the average miles run and the maintenance costs.

Number of Passenger Cars Owned per 100 Miles of Total Track.

1911.

N. Y. N. H. & H.	82.6	Penna. Co.	28.5
B. & M.	67.0	N. Y. C. & St. L.	15.7
N. Y. Central	41.6	Mich. Central	20.3
Penn. R. R.	35.5	Pere Marq.	15.5
D. & H.	33.1	P. C. C. & St. L.	24.7
D. L. & W.	60.4	Vandalia	18.8
Leh. Valley	26.2	C. C. C. & St. L.	21.0
P. & R.	52.6	Wabash	16.3
C. R. R. of N. J.	69.0	C. & A.	17.2
Erie	38.8	M. St. P. & S. S. M.	9.0
B. & O.	20.3	C. G. W.	13.0
N. & W.	16.8	Ill. Central	16.5
C. & O.	13.5	C. B. & Q.	13.1
A. C. L.	13.0	C. & N. W.	19.5
S. A. L.	11.4	C. R. I. & P.	13.3
Sou. Ry	14.4	Union Pac.	12.8
L. & N.	12.7	Santa Fe Sys.	13.7
M. & O.	11.7	Sou. Pac.	21.7
Nash. C. & St. L.	19.3	Nor. Pac.	16.7
L. S. & M. S.	24.7	Grt. Nor.	13.3

For the purpose of studying the variation in the amount of passenger equipment and the volume of passenger traffic, two tables and illustrative charts are submitted, showing the number of passenger cars owned per 100 miles of total track (exclusive of yards and sidings), Fig. 46, and the traffic density, *i. e.*, 1,000 passenger miles per mile of total track, Fig. 47, for the same railroads, illustrated in Figs. 43, 44 and 45.

Comparison of the two tables indicates as extensive variation in the number of passenger cars per mile of track as in the traffic density, as the number of cars owned varies from 9.0 on the "Soo Line" to 82.6 cars on the New Haven—a difference of 818 per cent.—and the traffic density varies from 56.2 on the Mobile & Ohio to 498.3 on the New Haven, a difference of 803 per cent.

A close study of the two tables, however, reveals that a direct relation does not exist between the amount of equipment and the volume of traffic, particularly between roads similarly situated, as the following deductions from these tables serve to illustrate:

	Cars Owned	Traffic Density
N. Y., N. H. & H.	82.6	498.3
Reading	52.6	252.6
D. & H.	33.1	116.5
Leh. Valley	26.2	121.2

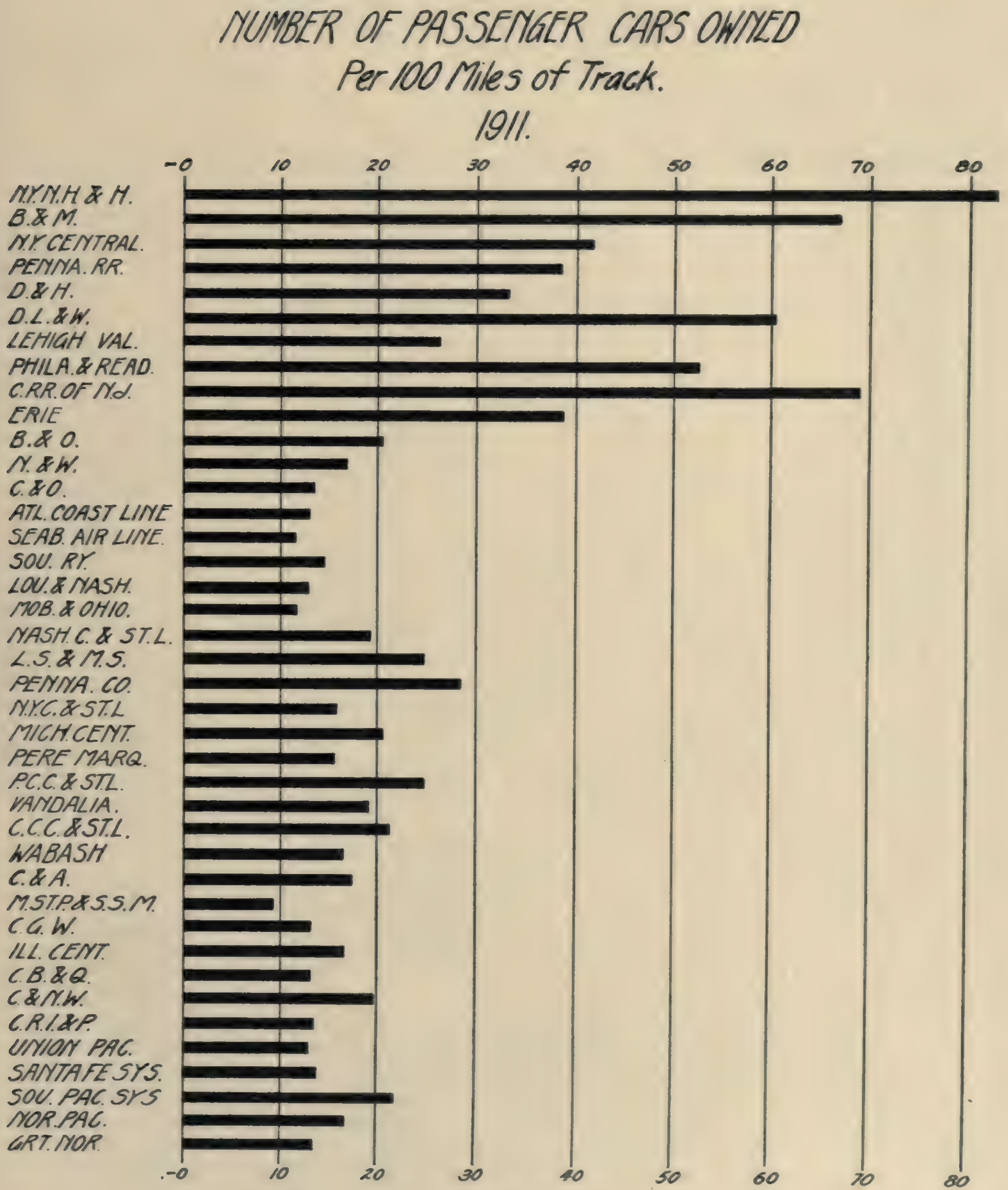

NUMBER OF PASSENGER CARS OWNED
Per 100 Miles of Track.
1911.
-0
10
20
30
40
50
60
70
80
N.Y.N.H. & H.
B. & M.
N.Y. CENTRAL.
PENNA. RR.
D. & H.
D.L. & W.
LEHIGH VAL.
PHILA. & READ.
C.RR. OF N.J.
ERIE
B. & O.
N. & W.
C. & O.
ATL. COAST LINE
SEAB. AIR LINE.
SOU. RY.
LOU. & NASH.
MOB. & OHIO.
NASH. C. & ST. L.
L.S. & M.S.
PENNA. CO.
N.Y.C. & ST. L
MICH. CENT.
PERE MARQ.
P.C.C. & ST. L.
VANDALIA.
C.C.C. & ST. L.
WABASH
C. & A.
M. ST. P. & S.S.M.
C.G.W.
ILL. CENT.
C.B. & Q.
C. & N.W.
C.R.I. & P.
UNION PAC.
SANTA FE SYS.
SOU. PAC. SYS
NOR. PAC.
GRT. NOR.

FIG. 46

PASSENGER TRAFFIC DENSITY.

1,000 PASSENGER MILES PER MILE OF TRACK.

1911.

N. Y. N. H. & H.	498.3	Penna. Co.	193.6
B. & M.	301.6	N. Y. C. & St. L.	152.5
N. Y. Central	298.5	Mich. Central	155.6
Penn. R. R.	270.0	Pere Marq	86.9
D. & H.	116.5	P. C. C. & St. L.	198.1
D. L. & W.	349.1	Vandalia	130.7
Lehigh Valley	121.2	C. C. C. & St. L.	183.8
P. & R.	252.6	Wabash	147.0
C. R. R. of N. J.	349.8	C. & A.	177.6
Erie	198.5	M. St. P. & S. S. M.	66.8
B. & O.	136.6	C. G. W.	93.2
N. & W.	80.9	Ill. Central	130.5
C. & O.	95.9	C. B. & Q.	119.5
A. C. L.	75.6	C. & N. W.	120.1
S. A. L.	72.5	C. R. I. & P.	124.3
Sou. Ry.	100.4	Union Pac.	137.0
L. & N.	106.8	Santa Fe Sys.	118.9
M. & O.	56.2	Sou. Pac. Sys.	191.3
Nash. C. & St. L.	95.4	Nor. Pac.	109.0
L. S. & M. S.	213.5	Grt. Nor.	78.8

Among the eastern roads the Reading, with a traffic density of approximately 50 per cent. of the New Haven, has 63.7 per cent. as much equipment per mile as the latter road. The Lehigh Valley, with 4 per cent. greater volume of traffic than the Delaware & Hudson, handles it with 21 per cent. less equipment on the same basis.

	Cars Owned	Traffic Density
C. & O.	13.5	95.9
N. & W.	16.8	80.9
L. & N.	12.7	106.8
N. C. & St. L.	19.3	95.4

In the south the Norfolk & Western requires 24.5 per cent. more equipment per mile than the Chesapeake & Ohio with 15.6 per cent. less traffic density. The Louisville & Nashville with 34.3 per cent. less equipment handles a volume of traffic on the same basis 11.8 per cent. greater than the Nashville, Chattanooga & St. Louis.

	Cars Owned	Traffic Density
Mich. Cent.	20.3	155.6
Pere Marq.	15.5	86.9
Northwestern	19.5	120.1
Burlington	13.1	119.5

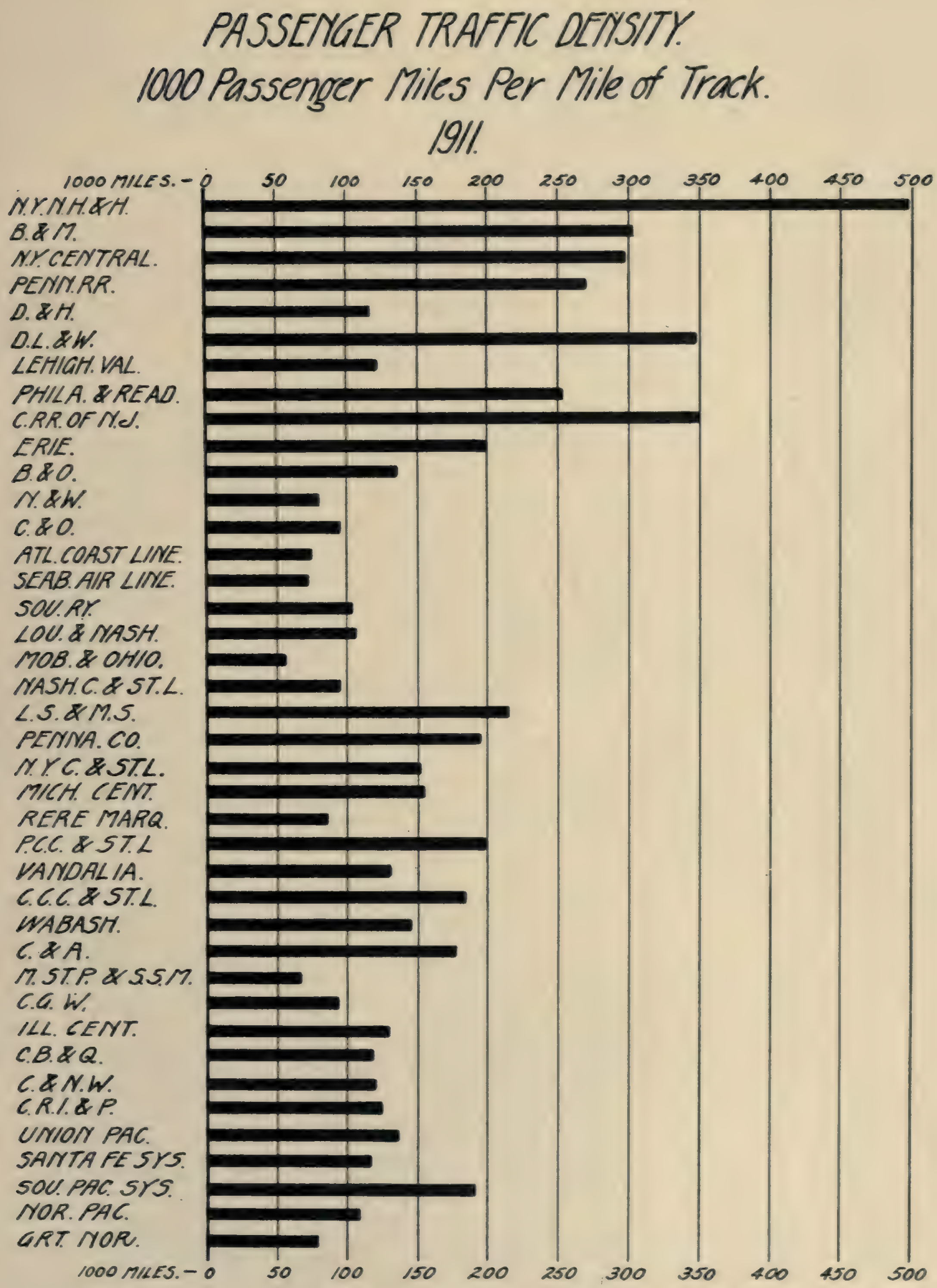

PASSENGER TRAFFIC DENSITY.
1000 Passenger Miles Per Mile of Track.
1911.
1000 MILES.— 0 50 100 150 200 250 300 350 400 450 500
N.Y.N.H.&H.
B.&M.
N.Y. CENTRAL.
PENN. RR.
D.&H.
D.L.&W.
LEHIGH. VAL.
PHILA.&READ.
C.RR.OF N.J.
ERIE.
B.&O.
N.&W.
C.&O.
ATL. COAST LINE.
SEAB. AIR LINE.
SOU. RY.
LOU.&NASH.
MOB.&OHIO.
NASH.C.&ST.L.
L.S.&M.S.
PENNA. CO.
N.Y.C.&ST.L.
MICH. CENT.
RERE MARQ.
P.C.C.&ST.L
VANDALIA.
C.C.C.&ST.L.
WABASH.
C.&A.
M.ST.P.&S.S.M.
C.G.W.
ILL. CENT.
C.B.&Q.
C.&N.W.
C.R.I.&P.
UNION PAC.
SANTA FE SYS.
SOU. PAC. SYS.
NOR. PAC.
GRT. NOR.
1000 MILES.— 0 50 100 150 200 250 300 350 400 450 500

FIG. 47

In the middle states the Michigan Central requires but 31 per cent. more equipment per mile than the Pere Marquette, when the volume of traffic is 79.2 per cent. in excess of the latter road. With equal traffic densities the Northwestern has in service 48.8 per cent. more passenger cars per mile of track than the Burlington.

	Cars Owned	Traffic Density
Union Pacific	12.8	137.0
Great Northern	13.3	78.8

On western roads the Great Northern owns 3.8 per cent. more passenger equipment per mile of track, while the volume of traffic is 42.5 per cent. less than the Union Pacific.

Further study discloses a probable reason for these variations, *i. e.,* the interchange of passenger equipment.

While the interchange of passenger cars is not nearly as extensive as that of freight, the passenger traffic agreements among various connecting trans-continental lines are sufficient to make the foreign car mileage an important item, exerting influence upon both equipment requirements and maintenance costs.

The Union Pacific, for example, had sufficient traffic agreements so that 40 per cent. of the total passenger car mileage credited to that road in 1910 was made by foreign cars. It is evident that such extensive interchange will modify any conclusions that may be reached as to mileage or maintenance costs of passenger equipment, though unfortunately the necessary data is not contained in the Interstate Commerce Commission records.

In order to make a thorough analysis of passenger car maintenance on any railroad it is necessary, in addition to the type and construction of equipment, to know the gross ton mileage and maintenance costs of the cars owned and the maintenance and the gross ton mileage of foreign cars handled by that particular road. It is to be hoped the Interstate Commerce Commission will appreciate the importance of having this data on file for the purpose of permitting conclusive analytical studies.

Shop Machinery and Tools.

Having thus treated on the maintenance of freight cars, locomotives and passenger cars, which items constitute 80 per cent. of the total maintenance of equipment expenses and 12 per cent. is consumed by depreciation charges, there are but few items further that are worthy of consideration.

As most railroads keep a record of the maintenance of shop machinery and tools, which costs are approximately 3 per cent. of the total maintenance of equipment, the figures for the representative roads are shown herewith. These expenses are to a large extent dependent upon the size and number of locomotives repaired and the locomotive tractive mile is the comparative unit employed in the accompanying table and chart, Fig. 48.

As previously stated, the subjects which have been considered constitute the principal items of equipment, though some few railroads have maintenance of elec-

tric locomotives, maintenance of floating equipment, which consume a considerable portion of their total maintenance of equipment costs. These items are, however, confined to such a few railroads that a study of their maintenance costs is not of sufficient advantage to be given consideration at this time.

Maintenance of Shop Machinery and Tools per Locomotive Tractive Mile.

1911.

	Cents		Cents
N. Y. N. H. & H.	40.6	L. S. & M. S.	24.2
Penn. R. R.	29.5	P. C. C. & St. L.	26.7
N. Y. Central	21.6	Ill. Cent.	32.1
D. L. & W.	28.8	Wabash	19.8
D. & H.	17.4	C. & A.	23.7
Lehigh Valley	16.3	C. B. & Q.	26.8
C. R. R. of N. J.	31.5	C. R. I. & P.	18.4
P. & R.	31.3	Frisco	19.6
B. & O.	24.3	K. C. Sou.	24.7
Erie	26.4	M. K. & T.	18.4
Ches. & Ohio	25.0	Tex. & Pac.	48.7
Atl. Coast Line	23.2	Mo. Pac.	22.9
Seab. Air Line	19.3	M. St. P. & S. S. M.	20.6
Cent. of Geo.	32.1	C. G. W.	26.4
Southern	19.1	D. & R. G.	36.0
Lou. & Nash	20.9	Union Pac.	24.3
Nash. C. & St. L.	26.7	Santa Fe Sys.	18.2
Mob. & Ohio	20.9	Sou. Pac. Sys.	21.2

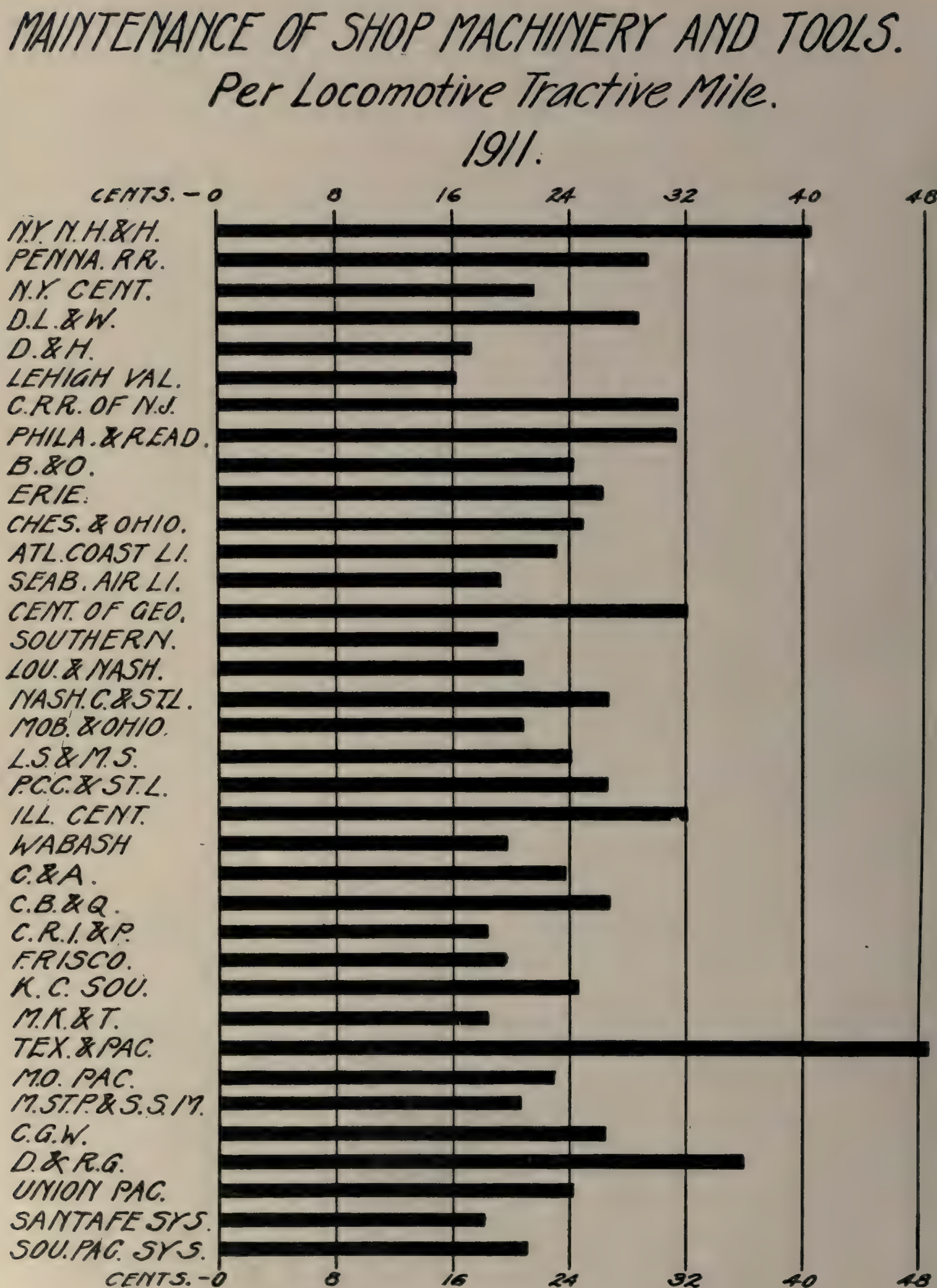

MAINTENANCE OF SHOP MACHINERY AND TOOLS.
Per Locomotive Tractive Mile.
1911.
CENTS. – 0
8
16
24
32
40
48
N.Y. N.H.&H.
PENNA. R.R.
N.Y. CENT.
D.L.&W.
D.&H.
LEHIGH VAL.
C.R.R. OF N.J.
PHILA.&READ.
B.&O.
ERIE.
CHES.&OHIO.
ATL.COAST LI.
SEAB. AIR LI.
CENT. OF GEO.
SOUTHERN.
LOU.&NASH.
NASH.C.&ST.L.
MOB.&OHIO.
L.S.&M.S.
P.C.C.&ST.L.
ILL. CENT.
WABASH
C.&A.
C.B.&Q.
C.R.I.&P.
FRISCO.
K.C. SOU.
M.K.&T.
TEX.&PAC.
MO. PAC.
M.ST.P.&S.S.M.
C.G.W.
D.&R.G.
UNION PAC.
SANTAFE SYS.
SOU.PAC. SYS.
CENTS. – 0
8
16
24
32
40
48

FIG. 48

Conducting Transportation

CHAPTER VII.

From the nature of their service, railroads are public utility corporations. Primarily they are privately owned commercial enterprises engaged in the manufacture of transportation for profit. For delivering transportation to the commonwealth railroads have built up great manufacturing structures and manned them with vast organizations of men.

In previous chapters the maintenance of the manufacturing property, namely, roadway, rolling stock and subsidiary branches, have been considered. The operation of the property and the various items entering into conducting transportation will be discussed in this chapter of the series.

Conducting transportation is the largest of the main divisions of expenses, absorbing more than one-half of the total expense of operation. As outlined in a previous chapter, the ratio of conducting transportation to total expense has been decreasing during the past decade, while maintenance of property has increased in similar proportion. Analogy was drawn between improved transportation facilities and lower costs of operation. That a relation on this basis does exist is quite clearly shown in Fig. 49.

The relative proportion of conducting transportation and maintenance of property to total operating expense for the years 1901 and 1910, with the per cent. increase and decrease in the latter over the former year, is as follows:

	1901	1910	Increase	Decrease
Conducting Transportation...	54.9%	53.3%	.....	1.6%
Maintenance of Property.....	40.9%	43.7%	2.6%	.....

Referring to Fig. 49, it is observed that the ratio of conducting transportation to total operating expense has decreased on an average for the ten-year period of nearly 0.2 per cent. per year. An average ratio line is added to the chart to show this.

The accompanying table, illustrated in Fig. 50, shows the wide variation in this ratio among the leading railroads of the country for the year 1911.

The extremes are the Louisville & Nashville and the Chesapeake & Ohio, each with a ratio of 45.7 per cent., and the Boston & Maine with a ratio of 60.4 per cent.

Unlike the maintenance accounts there is a direct relation between transportation expenses and the amount of business handled. The maintenance of way and structures expenses can be reduced for a limited period irrespective of the business handled; the renewals of ties, rails, ballast or bridges may be neglected for a con-

siderable length of time, though such a method of decreasing expenses will make itself very evident in a future period, so that a comparison of these expenses must extend over a period of several years.

Through large additions of new power or rolling stock, the maintenance of equipment expenses may be greatly reduced for a short time, hence a comparison of one year's maintenance costs may result in erroneous conclusions.

RATIO OF MAINTENANCE OF PROPERTY AND CONDUCTING TRANSPORTATION TO TOTAL OPERATING EXPENSE.

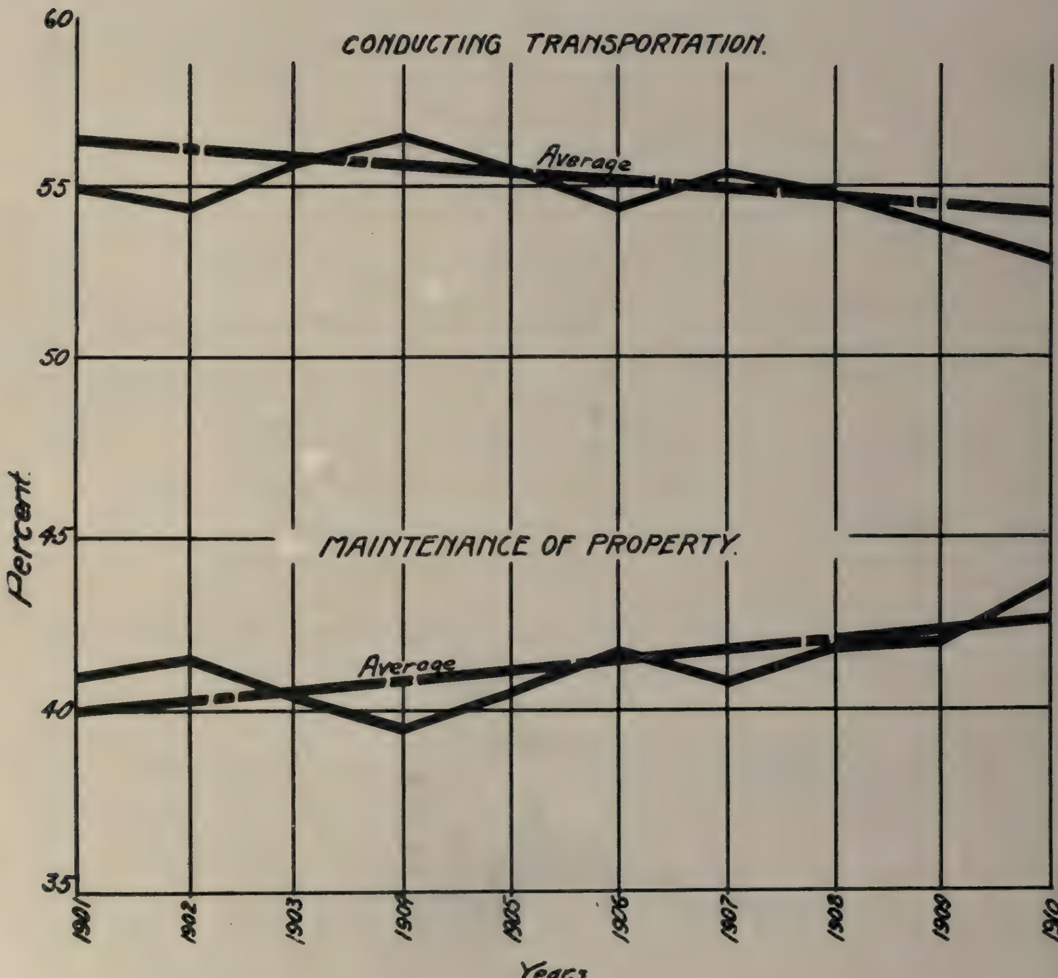


Fig. 49

PERCENTAGE OF TRANSPORTATION EXPENSES TO OPERATING EXPENSES.

1911.

N. Y. N. H. & H.	60.0%	Vandalia	51.8%
B. & M.	60.4	P. C. C. & St. L.	51.9
N. Y. Central	51.4	C. H. & D.	58.7
Penn. R. R.	51.0	L. E. & W.	48.6
Erie	51.0	P. & L. E.	48.9
B. & O.	49.3	Ill. Central	48.7
D. & H.	57.4	C. B. & Q.	47.9
D. L. & W.	49.7	C. & N. W.	58.2
Lehigh Valley	51.2	M. St. P. & S. S. M.	55.3
Phil. & Read	51.2	C. G. W.	53.6
Ches. & Ohio	45.7	C. R. I. & P.	53.3
Nor. & West	46.5	Frisco	53.6
Atl. Coast Line	51.6	M. K. & T.	55.5
Seab. Air Line	51.3	C. & A.	51.7
Southern	50.0	Union Pac.	48.9
Lou. & Nash	45.7	Santa Fe Sys.	46.9
Nash. C. & St. L.	47.7	Sou. Pac. Sys.	49.1
L. S. & M. S.	49.3	C. M. & St. P.	59.4
Penn. Co.	51.9	Nor. Pac.	54.4
C. C. C. & St. L.	54.5	Grt. Nor.	48.0

COST OF CONDUCTING TRANSPORTATION PER 1,000 TRAIN MILES.

1911.

N. Y. N. H. & H.	$1,041	Vandalia	$671
B. & M.	956	P. C. C. & St. L.	755
N. Y. Central	795	C. H. & D.	835
Penn. R. R.	1,017	L. E. & W.	664
Erie	803	P. & L. E.	1,237
B. & O.	772	Ill. Central	681
D. & H.	861	C. B. & Q.	820
D. L. & W.	885	C. & N. W.	803
Lehigh Valley	874	M. St. P. & S. S. M.	718
Phil. & Read	882	C. G. W.	803
Ches. & Ohio	674	C. R. I. & P.	743
N. & W.	699	Frisco	685
Atl. Coast Line	623	M. K. & T.	782
Seab. Air Line	641	C. & A.	741
Southern	634	Union Pac.	745
Lou. & Nash.	626	Santa Fe Sys.	778
Nash. C. & St. L.	613	Sou. Pac. Sys.	914
L. S. & M. S.	867	C. M. & St. P.	856
Penn. Co.	819	Nor. Pac.	991
C. C. C. & St. L.	775	Grt. Nor.	827

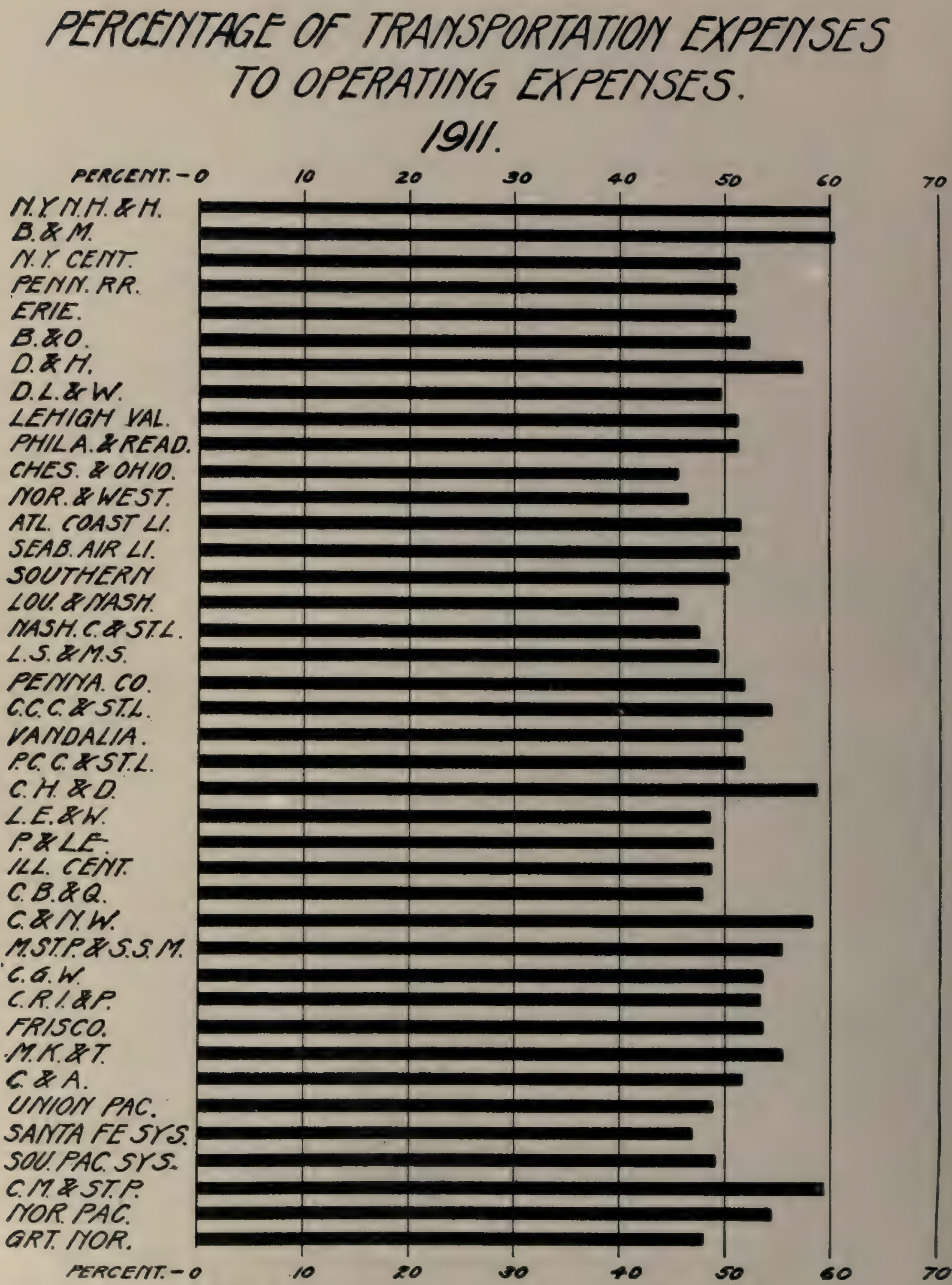

PERCENTAGE OF TRANSPORTATION EXPENSES
TO OPERATING EXPENSES.
1911.
PERCENT.-0
10
20
30
40
50
60
70
N.Y.N.H.&H.
B.&M.
N.Y. CENT.
PENN. RR.
ERIE.
B.&O.
D.&H.
D.L.&W.
LEHIGH VAL.
PHILA.&READ.
CHES. & OHIO.
NOR. & WEST.
ATL. COAST LI.
SEAB. AIR LI.
SOUTHERN
LOU. & NASH.
NASH. C.&ST.L.
L.S.&M.S.
PENNA. CO.
C.C.C.&ST.L.
VANDALIA.
P.C.C.&ST.L.
C.H.&D.
L.E.&W.
P.&L.E.
ILL. CENT.
C.B.&Q.
C.&N.W.
M.ST.P.&S.S.M.
C.G.W.
C.R.I.&P.
FRISCO.
M.K.&T.
C.&A.
UNION PAC.
SANTA FE SYS.
SOU. PAC. SYS.
C.M.&ST.P.
NOR. PAC.
GRT. NOR.

Fig. 50

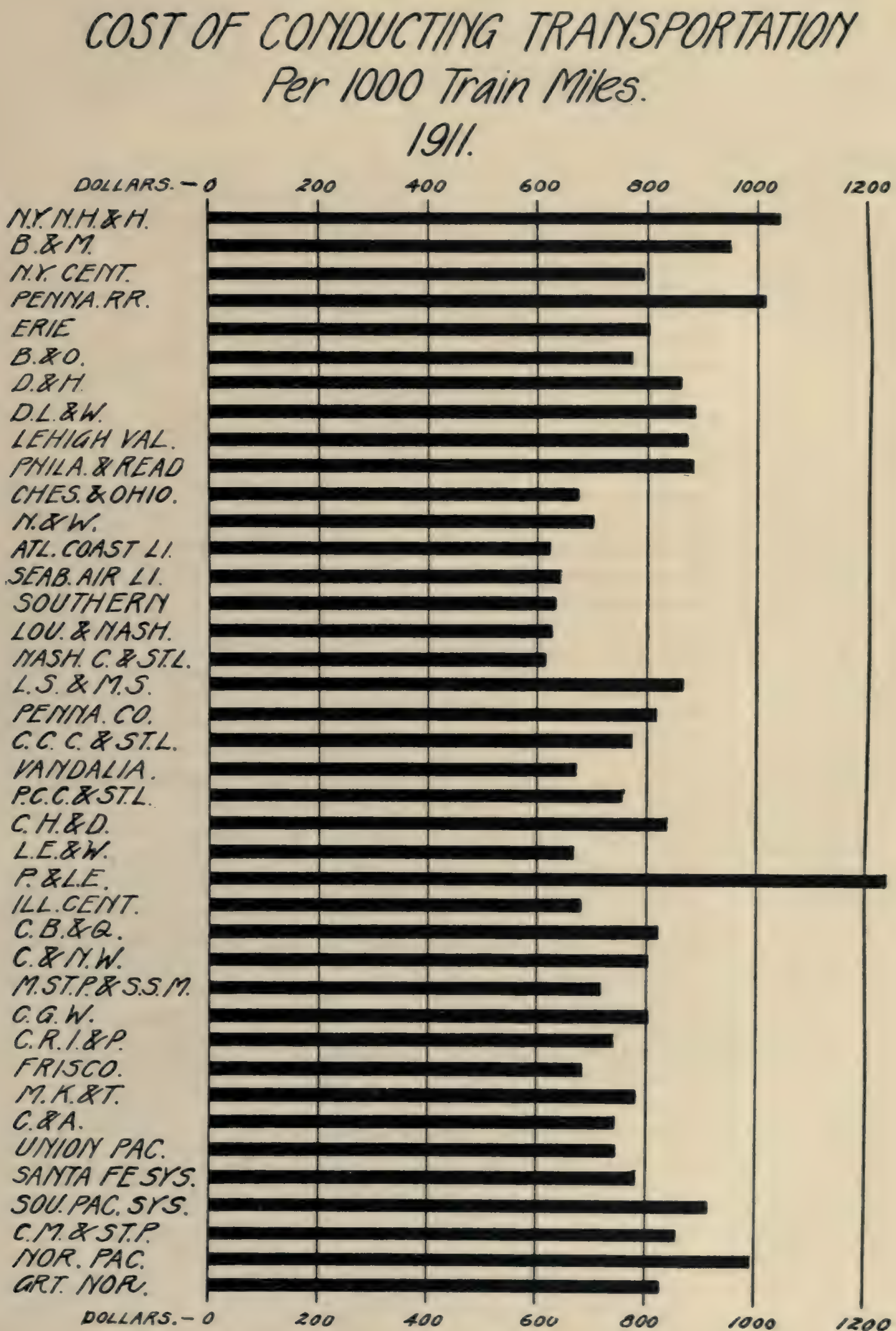

COST OF CONDUCTING TRANSPORTATION
Per 1000 Train Miles.
1911.
DOLLARS.— 0
200
400
600
800
1000
1200
N.Y. N.H. & H.
B. & M.
N.Y. CENT.
PENNA. RR.
ERIE
B. & O.
D. & H.
D.L. & W.
LEHIGH VAL.
PHILA. & READ
CHES. & OHIO.
N. & W.
ATL. COAST LI.
SEAB. AIR LI.
SOUTHERN
LOU. & NASH.
NASH. C. & ST.L.
L.S. & M.S.
PENNA. CO.
C.C.C. & ST.L.
VANDALIA.
P.C.C. & ST.L.
C.H. & D.
L.E. & W.
P. & L.E.
ILL. CENT.
C.B. & Q.
C. & N.W.
M.ST.P. & S.S.M.
C.G.W.
C.R.I. & P.
FRISCO.
M.K. & T.
C. & A.
UNION PAC.
SANTA FE SYS.
SOU. PAC. SYS.
C.M. & ST.P.
NOR. PAC.
GRT. NOR.
DOLLARS.— 0
200
400
600
800
1000
1200

FIG. 51

Not so with transportation expenses, as these are in direct relation to the amount of business handled. The usual method employed in comparing cost of conducting transportation is per train mile. Costs on this basis for the same representative roads previously illustrated are shown in Fig. 51 and accompanying table for the year 1911.

These figures show a variation from $623 per 1,000 train miles on the Atlantic Coast Line to $1,237 on the Pittsburg & Lake Erie, a difference of 99 per cent.

For the purpose of analysis, the principal items of expense in conducting transportation are shown in the average per cent. of total in Fig. 52, as follows:

Enginemen, Yard and Trainmen	34%
Locomotive Fuel	25
Station Men and Dispatching	17
Claims, Damages and Miscellaneous Expense	11
Engine House, Engine Supplies and Expenses	6
Train Supplies and Expenses	4
Supervision	3

Careful analysis of these expenses discloses many items that are not dependent upon the discretion of the management and consequently any deductions of the performance on the train mile basis for the same railroad during different periods, or among various railroads for the same period, may be unfair, as each item of this expense must be given separate study.

The wages of yardmen, trainmen and enginemen constitute approximately 34 per cent. of the total, while the wages of station employes and train dispatchers are approximately 17 per cent., so that these expenses, which are essentially labor items, make up 50 per cent. of the total cost of conducting transportation.

The cost of conducting transportation is more than one-half the operating expenses and the wages paid the above classes of labor approximates 25 per cent. of the total operating expenses.

As the earnings of these employes are dependent upon the hours occupied in performance of their work, rather than upon the volume of business, a 25 per cent. increase in their wages will effect a 6 per cent. increase in the total operating expenses.

It is therefore logical to say that one-half the cost of conducting transportation, or one-fourth the total operating expenses, is independent of the skill of the individual or the administrative ability of the supervising officer.

Locomotive fuel, the largest single item of expense in railroad operation is of such importance that the following and concluding chapter of this treatise is devoted entirely to this one item and need only be mentioned at this time.

The remaining 24 per cent. of the total cost of conducting transportation is divided as follows:

Claims, Damages and Miscellaneous Expenses	11%
Engine House Expenses and Engine Supplies	6
Train Supplies and Expenses	4
Supervision	3

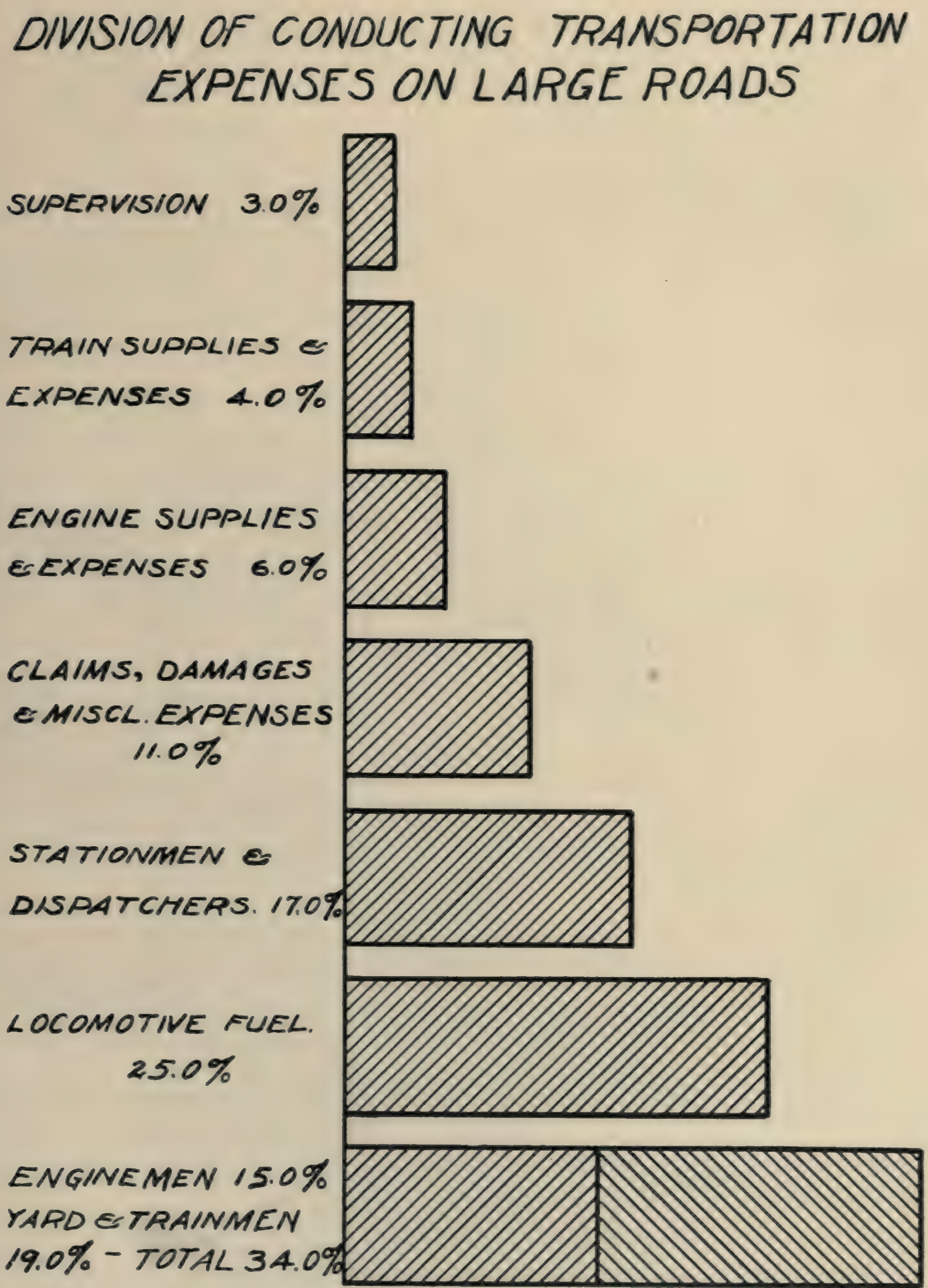

DIVISION OF CONDUCTING TRANSPORTATION
EXPENSES ON LARGE ROADS
SUPERVISION 3.0%
TRAIN SUPPLIES & EXPENSES 4.0%
ENGINE SUPPLIES & EXPENSES 6.0%
CLAIMS, DAMAGES & MISCL. EXPENSES 11.0%
STATIONMEN & DISPATCHERS. 17.0%
LOCOMOTIVE FUEL. 25.0%
ENGINEMEN 15.0%
YARD & TRAINMEN 19.0% - TOTAL 34.0%

Fig. 52

The first item, claims, etc., while aggregating 11 per cent. of the total, includes eighteen miscellaneous items so diversified as to afford no adequate unit of comparison, while the last item, that of supervision, is largely a fixed charge having no direct relation to the business handled.

Engine house expenses, covering the attendance at terminals and the cost of lubricants and supplies furnished locomotives, absorb 6 per cent. of the total cost of conducting transportation, while the expenses incidental to the handling and supplying of trains at terminals included in the item "train supplies and expenses" consume 4 per cent. of the total.

Engine house expenses, locomotive lubricants and supplies are dependent upon the size of and service rendered by the locomotives, and consequently the locomotive work unit or tractive mile is the equable basis for these items.

While these expenses are of minor importance in relation to the total cost of operation, considerable attention is directed by railroad operating officials, particularly mechanical officers, in the detail performance of these items, and statements and charts, Figs. 53, 54 and 55, showing the costs on a tractive mile basis are shown.

Train supplies and expenses are not dependent on the number of train miles, but upon the car mileage, but inasmuch as the expense of passenger equipment is greater than that of freight equipment, the comparison should be upon the basis of passenger car miles and freight car miles separately.

Unfortunately, the records of the Interstate Commerce Commission do not provide for the division of these expenses as between passenger and freight, so that satisfactory comparisons cannot be made at this time.

Engine House Expense per Tractive Mile.

1911.

N. Y. N. H. & H	$1.07	P. C. C. & St. L	$0.73
B. & M	1.06	Mich. Cent	.68
N. Y. Central	.85	C. H. & D	.90
Penn. R. R	.79	C. C. C. & St. L	.76
B. & O	.57	Vandalia	.99
Erie	1.08	Ill. Cent	1.13
D. & H	1.15	C. B. & Q	.95
D. L. & W	84	C. R. I. & P	.88
Lehigh Valley	.78	C. & N. W	1.22
P. & R	.97	Frisco	.72
C. R. R. of N. J	.88	M. K. & T	1.20
C. & O	.52	K. C. Sou	.94
N. & W	.70	C. G. W	1.10
Atl. Coast Line	.74	C. St. P. M. & O	1.18
Seab. Air Line	.42	M. St. P. & S. S. M	.99
Southern Ry	.62	Union Pac	.99
L. & N	.65	C. M. & St. P	1.40
Mob. & Ohio	.99	Santa Fe Sys	.96
Nash. C. & St. L	.62	Sou. Pac. Sys	.93
L. S. & M. S	.69	Nor. Pac	.91

Traffic Expense and General Expense.

The traffic expenses, together with the general expenses of a railroad, constitute approximately 7 per cent. of the total operating expenses, and are largely fixed charges.

Inasmuch as they bear no direct relation to the train mileage, engine mileage, car mileage, traffic density, geographical or topographical conditions, these expenses are not dependent upon the discretion of the operating officials and any study with reference to a comparative unit will be of doubtful value and is not given consideration.

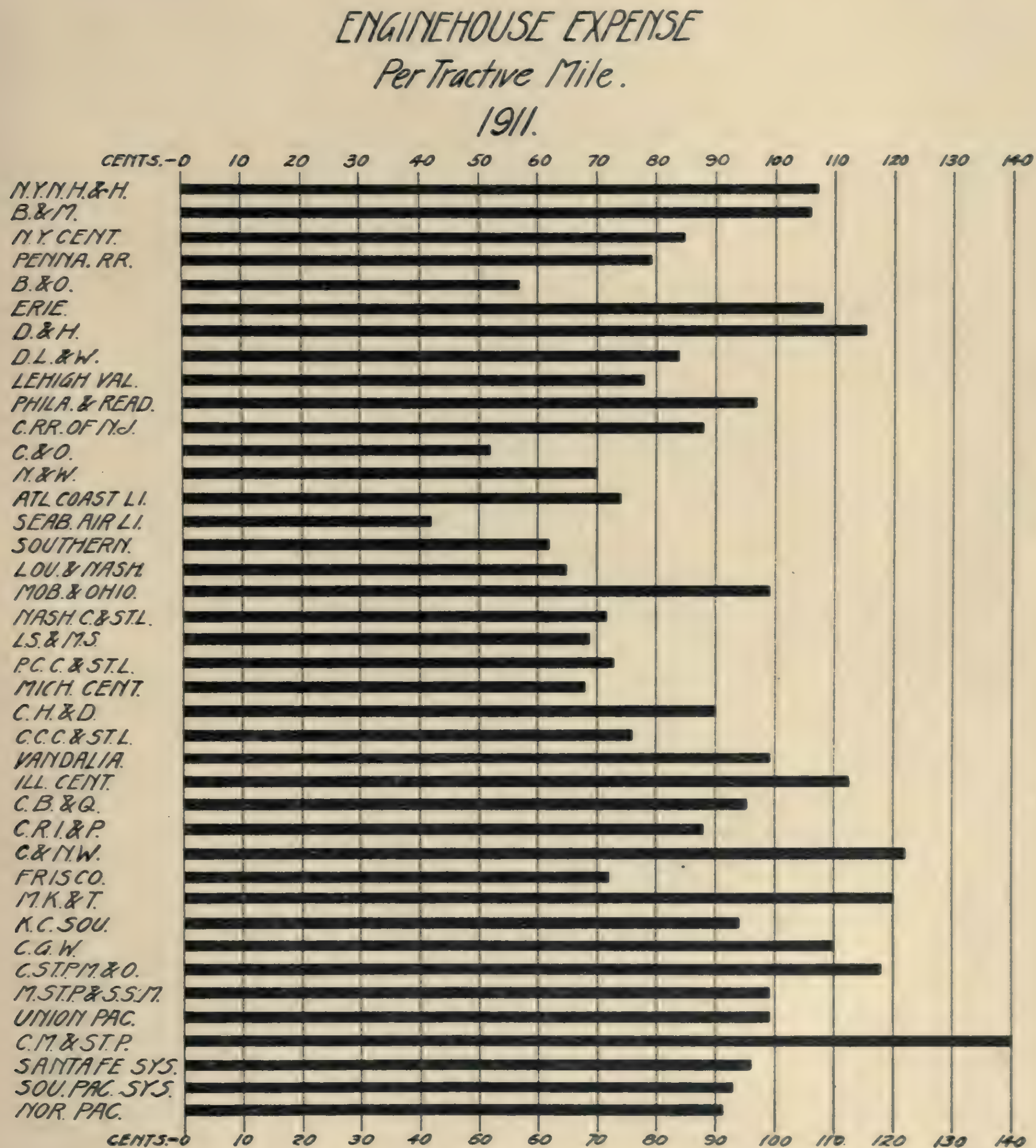


Fig. 53

Locomotive Lubricants per Tractive Mile.

1911.

	Cents		Cents
N. Y. N. H. & H.	13.9	L. S. & M. S.	7.1
B. & M.	7.3	Penn. Co.	7.9
N. Y. Central	8.5	P. C. C. & St. L.	8.1
Erie	9.3	Mich. Cent.	9.5
Penna. R. R.	7.2	Vandalia	9.2
B. & O.	6.4	C. C. C. & St. L.	8.6
D. & H.	10.8	C. & A.	8.2
D. L. & W.	8.9	Wabash	10.0
Lehigh Valley	7.7	C. B. & Q.	7.2
C. R. R. of N. J.	10.7	C. & N. W.	11.9
Phil. & Read	8.9	C. M. & St. P.	10.6
N. & W.	6.0	C. R. I. & P.	8.6
Ches. & Ohio	7.0	Frisco	8.8
Atl. Coast Line	11.3	M. K. & T.	11.1
Seab. Air Line	7.7	Mo. Pac.	7.0
Cent. of Geo.	5.7	D. & R. G.	12.1
Southern	5.4	Santa Fe Sys.	10.0
Lou. & Nash.	8.5	Union Pac.	6.3
Nash. C. & St. L.	10.6	Sou. Pac. Sys.	8.7
Ill. Cent.	10.9	Grt. Nor.	9.3

Locomotive Supplies per Tractive Mile.

1911.

	Cents		Cents
N. Y. N. H. & H.	13.5	L. S. & M. S.	6.7
B. & M.	8.2	Penn. Co.	7.3
N. Y. Central	6.6	P. C. C. & St. L.	10.4
Erie	8.9	Mich. Cent.	5.9
Penn. R. R.	9.2	Vandalia	10.1
B. & O.	9.2	C. C. C. & St. L.	11.4
D. & H.	8.2	C. & A.	9.2
D. L. & W.	11.0	Wabash	8.6
Lehigh Valley	7.3	C. B. & Q.	9.1
C. R. R. of N. J.	10.2	C. & N. W.	9.9
Phil. & Read	13.0	C. M. & St. P.	13.8
N. & W.	7.5	C. R. I. & P.	7.5
Ches. & Ohio	11.0	Frisco	10.1
Atl. Coast Line	8.4	M. K. & T.	8.9
Seab. Air Line	8.6	Mo. Pac.	12.1
Cent. of Geo.	6.4	D. & R. G.	17.8
Southern	6.1	Santa Fe Sys.	5.6
Lou. & Nash.	10.5	Union Pac.	9.4
Nash. C. & St. L.	6.8	Sou. Pac. Sys.	11.1
Ill. Central	8.5	Grt. Nor.	8.0

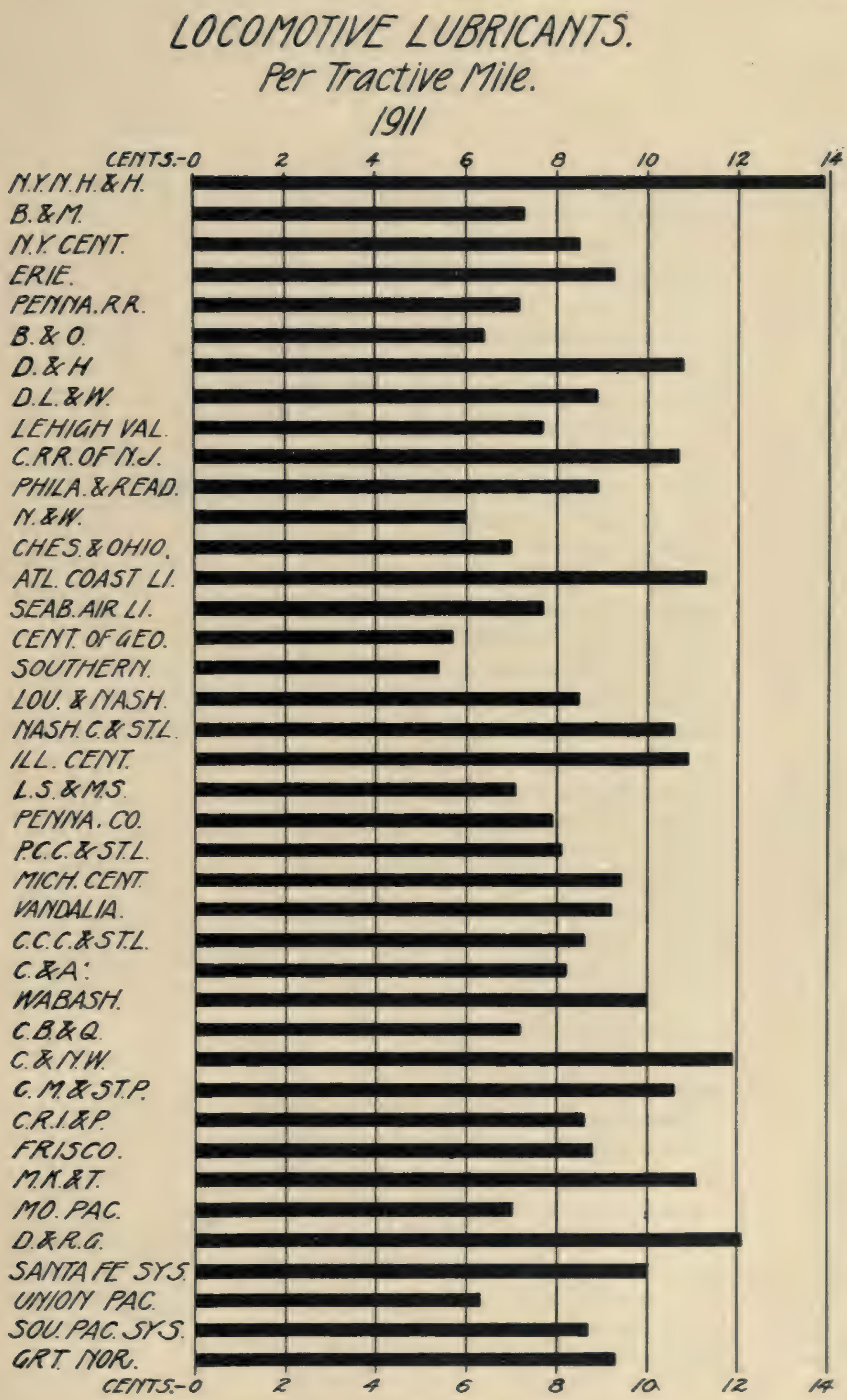
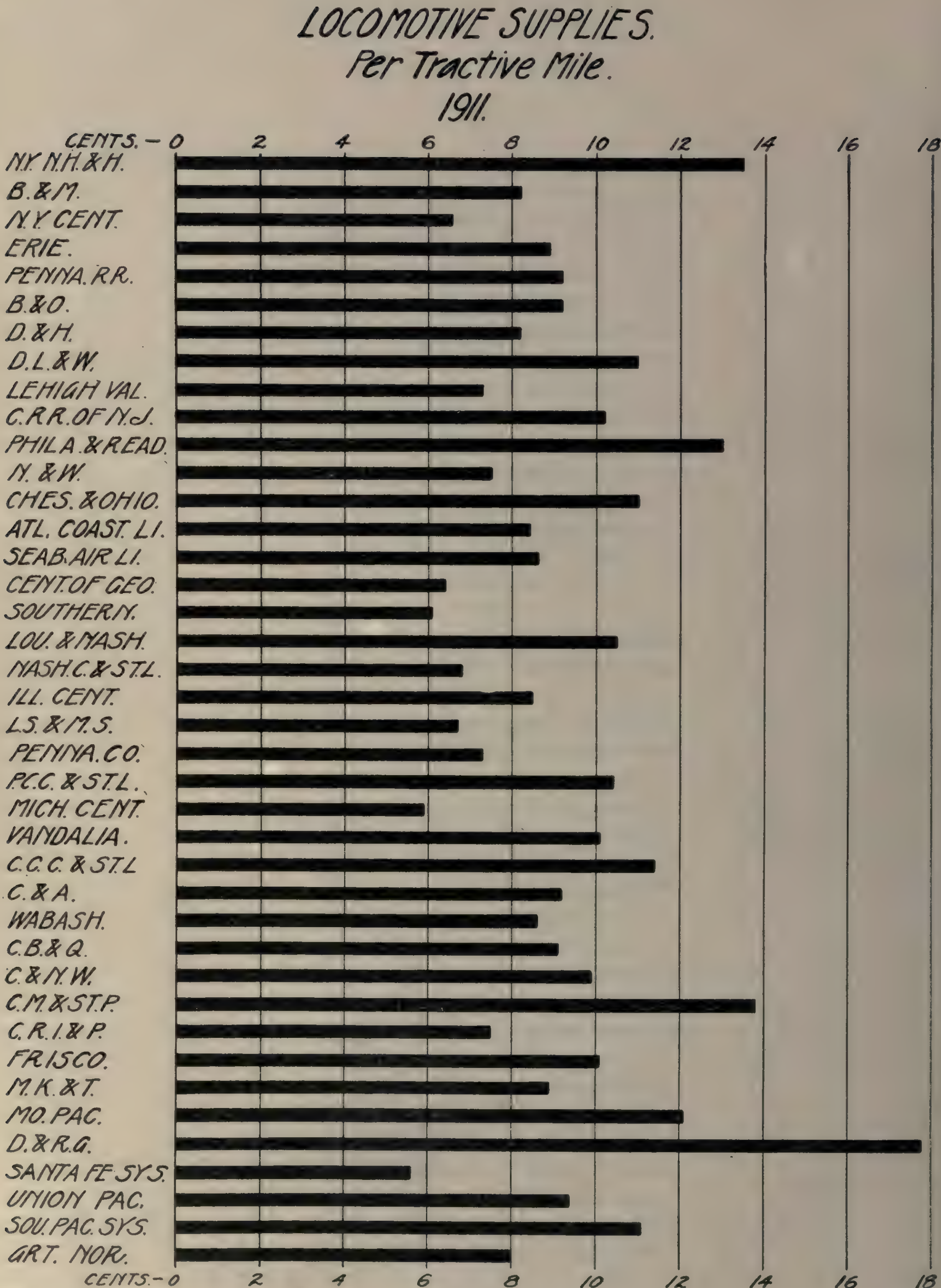

LOCOMOTIVE LUBRICANTS.
Per Tractive Mile.
1911
CENTS:-0 2 4 6 8 10 12 14
N.Y.N.H.&H.
B.&M.
N.Y.CENT.
ERIE.
PENNA.R.R.
B.&O.
D.&H
D.L.&W.
LEHIGH VAL.
C.R.R.OF N.J.
PHILA.&READ.
N.&W.
CHES.&OHIO.
ATL. COAST LI.
SEAB.AIR LI.
CENT. OF GEO.
SOUTHERN.
LOU.&NASH.
NASH.C.&ST.L.
ILL. CENT.
L.S.&M.S.
PENNA. CO.
P.C.C.&ST.L.
MICH. CENT.
VANDALIA.
C.C.C.&ST.L.
C.&A.
WABASH.
C.B.&Q.
C.&N.W.
C.M.&ST.P.
C.R.I.&P.
FRISCO.
M.K.&T.
MO.PAC.
D.&R.G.
SANTA FE SYS.
UNION PAC.
SOU.PAC.SYS.
GRT. NOR.
CENTS:-0 2 4 6 8 10 12 14

FIG. 54



LOCOMOTIVE SUPPLIES.
Per Tractive Mile.
1911.
CENTS. – 0 2 4 6 8 10 12 14 16 18
N.Y. N.H. & H.
B. & M.
N.Y. CENT.
ERIE.
PENNA. R.R.
B. & O.
D. & H.
D.L. & W.
LEHIGH VAL.
C.R.R. OF N.J.
PHILA. & READ.
N. & W.
CHES. & OHIO.
ATL. COAST LI.
SEAB. AIR LI.
CENT. OF GEO.
SOUTHERN.
LOU. & NASH.
NASH. C. & ST. L.
ILL. CENT.
L.S. & M.S.
PENNA. CO.
P.C.C. & ST. L.
MICH. CENT.
VANDALIA.
C.C.C. & ST. L.
C. & A.
WABASH.
C.B. & Q.
C. & N.W.
C.M. & ST. P.
C.R.I. & P.
FRISCO.
M.K. & T.
MO. PAC.
D. & R.G.
SANTA FE SYS.
UNION PAC.
SOU. PAC. SYS.
GRT. NOR.
CENTS. – 0 2 4 6 8 10 12 14 16 18

FIG. 55

Fuel

CHAPTER VIII.

The fuel consumed by locomotives on the railroads of the United States during the fiscal year 1911 totaled 132,000,000 tons, which is equal to one-fifth of the entire annual output of the coal mines of the country. This item required an expenditure of about $240,000,000, or 12 per cent. of the total operating expenses of the railroads, and amounted to 62 per cent. of the expenditure for maintenance of way and structures and 52 per cent. of the expenditures for maintenance of equipment during that period.

During the past ten years the value of fuel used on locomotives by the railroads of the United States has steadily increased, and with the greater use of fuel for industrial purposes, the larger expense of mining, it is evident that the cost of this item of railroad operation must continue to increase rather than to diminish in the future. This is not only a matter of immense moment to the railways, but it is an important economic factor which justifies closer study of conservationists for the purpose of determining whether there may be any method by which such a vast consumption may be diminished.

The importance of this was sufficiently recognized by the United States Government, and in 1906 arrangements were made to have Dr. W. F. M. Goss conduct a series of tests for the purpose of determining the best methods for utilization of fuel in locomotive practice. These tests were conducted with a single expansion locomotive equipped with a superheater, and the results were given to the public in a bulletin issued by the United States Geological Survey.

As a result of these tests, Dr. Goss has demonstrated that under ideal conditions, of all the available heat in the fuel consumed by a locomotive, 57 per cent. is absorbed by the boiler and superheater and the other 43 per cent. is distributed in heat losses as follows:

Products of combustion....................................	19%
Imperfect combustion......................................	17
External radiation and leaking............................	7

In drawing the general conclusion as to the result of these tests, Dr. Goss states as follows:

> "It is apparent that the utilization of fuel in locomotive service is a problem of so large a proportion that if even a small saving could be made by all or a large proportion of the locomotives of the country, it would constitute an important factor in the conservation of the nation's fuel supply.

> "Locomotive boilers are handicapped by the requirement that the boiler itself and all of its appurtenances must come within rigidly defined limits of space, and by the fact that they are forced to work at a very high rate of power.
>
> "Notwithstanding this handicap, it is apparent that the zone of practical improvement which lies between present day results and those which may reasonably be regarded as obtainable is not so wide as to make future progress rapid or easy.
>
> "Material improvement is less likely to come in large measures as the result of revolutionary changes than as a series of relatively small savings in the several items to which attention has been called."

From the foregoing it is apparent that fuel economy must be secured in the following:

Reduction in losses due to imperfect combustion.
Greater utilization of heat in escaping gases.
Increased evaporation per pound of coal.
Improved economy in steam consumption.

For a number of years the Railway Master Mechanics Association have been making exhaustive tests for determining the best design of draft appliances and of arches in the fireboxes, for the purpose of reducing the losses due to imperfect combustion.

Inasmuch as the locomotive used by Dr. Goss in his tests was equipped with a very efficient superheater, it is doubtful if much additional economy in the second item can be expected through improvements, though recent designs of locomotives have feed-water heating devices for the purpose of using a portion of the heat now lost in escaping gases.

Effort is also being made to secure better circulation in the boiler and thus increase the evaporating efficiency of the coal.

The necessity of adequate supervision of this important item of operating expenses has also been recognized, and many railroads have well organized fuel departments under capable managers who direct the handling of fuel from the loading at the mine to the delivery to the locomotive. This has served to eliminate losses in transit and delivery and secured greater accuracy in records of disposition and disbursements.

Some railroad operating officials have extended the jurisdiction of their fuel supervisors to include the education of the enginemen in the best methods of firing, including the installation of suitable records of fuel performance. This has been a well-directed step, for vast improvement can be accomplished by the adoption of suitable accounting methods, whereby each engineman is charged with the amount of fuel actually taken and the establishment of proper standards so as to permit the performance of each individual to be accurately determined.

With such data available any divergence from standard performance can be readily detected, and such corrections made as seem necessary after thorough investigation. Chemical analysis of the various grades of coal used often confirms the deductions from these investigations, resulting in closer inspection of fuel

purchased. Modification of design in the locomotive appurtenances pertaining to combustion is often found to be advisable, further indicating the value of accurate records, proper standards and efficient administration.

While all of these methods have undoubtedly served to secure more economical fuel performance, it would appear that the most important item, viz., improved steam consumption, has been overlooked. Inasmuch as 57 per cent. of the available heat in the fuel is absorbed by the boiler and superheater, the greatest net economy can be effected by developing more horsepower per pound of steam.

The thermal efficiency of the single expansion locomotive, in actual service, averages from 3 to 4 per cent., and with the compound locomotive, equipped with superheaters and feed-water heaters, this figure is raised to 5 or 6 per cent. The thermal efficiency of the more refined marine engine averages from 12 to 15 per cent., and recent developments of a superheated steam unit in Germany have resulted in securing a thermal efficiency of 20 per cent.

If the thermal efficiency of the steam locomotive was increased to 10 per cent., the saving in fuel would amount to over $120,000,000 annually, which is equal to 6 per cent. on $2,000,000,000. Notwithstanding this, there has been no concentrated effort by railway mechanical officials to design a locomotive which would compare favorably with results obtained in marine practice or even in European locomotive practice.

In the locomotive tests conducted by the Pennsylvania Railroad at St. Louis in 1904, it was demonstrated that the coal consumption per dynamometer horsepower was 3.5 to 5 pounds for single expansion locomotives and 2.0 to 3.6 pounds for compound locomotives. The average fuel consumption of compounds was approximately 30 per cent. less than single expansion locomotives, which figures were later accepted by the Railway Master Mechanics Association.

In view of this, it is somewhat surprising, with locomotive fuel the largest single item of expense, to find from the records of the Interstate Commerce Commission that compound locomotives constitute only 7 per cent. of the total tractive force of the railroads in the country. Only four railroads have over 20 per cent. of their tractive force in compound locomotives and but eight others have over 10 per cent., while twenty-five of the leading railroads have no compound locomotives of any design in service.

Many conservative railroad mechanical officials have, however, refused to consider the question of compound locomotives, on the theory that the increased repair costs due to the more intricate machinery make it unwise to use compound locomotives, since the saving in fuel would be more than offset by the increased maintenance costs and the increased time out of service.

When it is considered that on some railroads the annual expenditure for locomotive fuel is twice and even three times the expenditure for locomotive maintenance, the matter should be thoroughly investigated before a decision is reached that compound locomotives are too expensive to maintain to be considered as power units.

In view of the absence of a satisfactory basis for comparing performance and costs, it is extremely doubtful if the situation has been thoroughly analyzed. The usual method of comparison has been on the basis of the cost per locomotive mile,

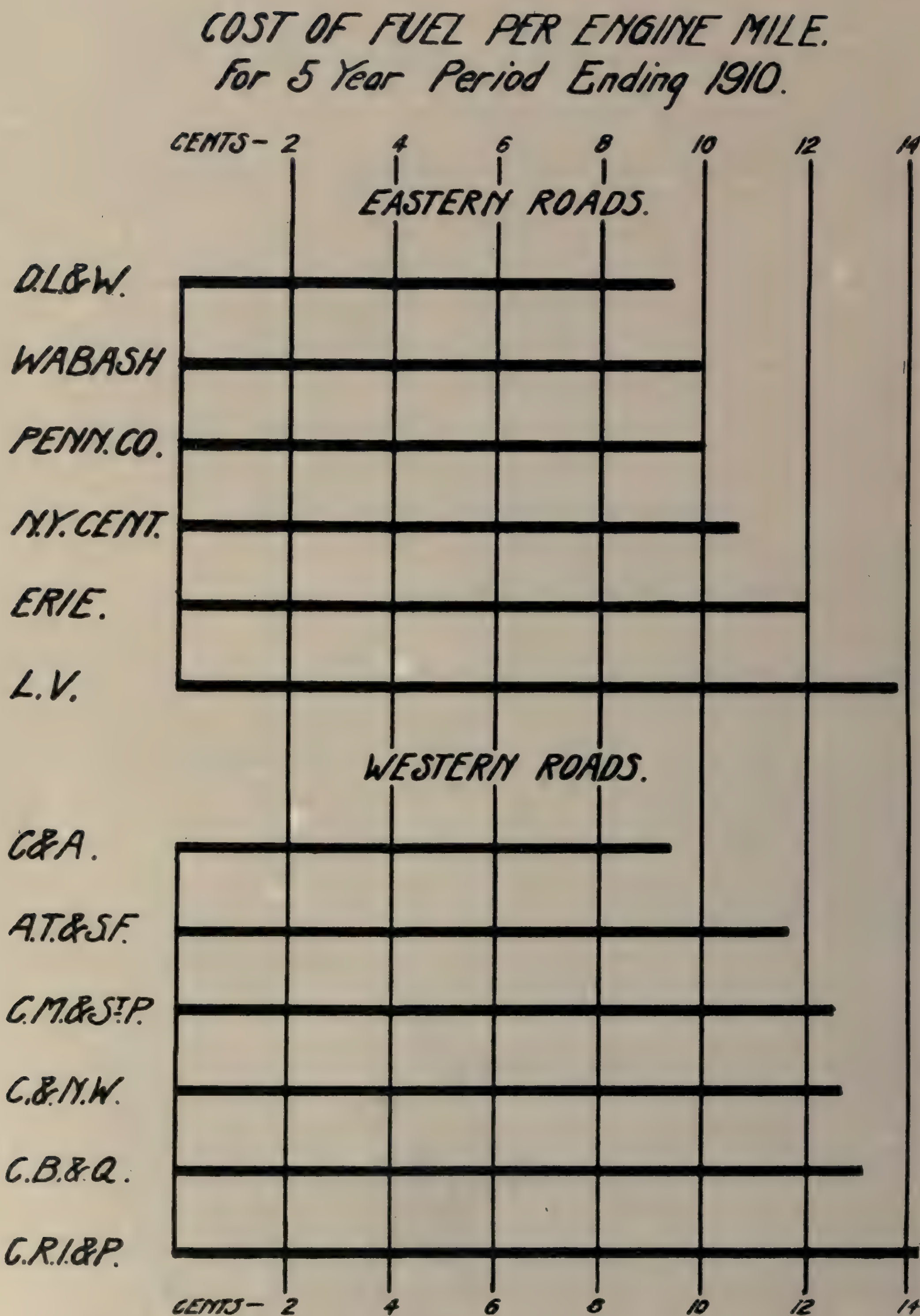

COST OF FUEL PER ENGINE MILE.
For 5 Year Period Ending 1910.
CENTS– 2 4 6 8 10 12 14
EASTERN ROADS.
D.L.&W.
WABASH
PENN.CO.
N.Y.CENT.
ERIE.
L.V.
WESTERN ROADS.
C&A.
A.T.&S.F.
C.M.&St.P.
C.&N.W.
C.B.&Q.
C.R.I.&P.
CENTS– 2 4 6 8 10 12 14

Fig. 56

and the writer has made an extensive study of the matter in order to determine the proper unit for comparative purposes.

The result of this study, which is given in the following pages, illustrates how easily erroneous conclusions may be drawn of locomotive performance in the absence of satisfactory comparative units, and serves to demonstrate that the maintenance costs and fuel consumption of compound and single expansion locomotives have not been given the consideration they warrant.

From the data compiled by the Interstate Commerce Commission for their use at the recent rate hearing, the cost of fuel per locomotive mile has been determined for six eastern and six western roads for the five-year periods ending 1905 and 1910, which information, shown graphically in Fig. 56, is as follows:

COST OF FUEL PER ENGINE MILE.

Eastern Roads	Average 5 Yrs. Ending 1905	Average 5 Yrs. Ending 1910	Per Cent. Increase
Penna. Railroad...............	9.5 cents	10.5 cents	10.5
Lehigh Valley.................	11.5	13.7	19.1
Erie	9.7	12.0	23.7
Wabash	7.4	9.9	33.8
N. Y. Central.................	7.9	10.7	35.4
D. L. & W.....................	6.7	9.4	40.3
Western Roads			
A. T. & S. F..................	10.1 cents	11.6 cents	14.8
C. M. & St. P.................	10.0	12.5	25.0
C. & A........................	7.0	9.3	32.8
C. B. & Q.....................	9.5	13.1	37.9
C. & N. W.....................	9.1	12.6	38.4
C. R. I & P...................	10.4	14.4	38.5

Comparing the cost of fuel per engine mile on the roads mentioned for the five-year period ending 1910, with the five-year period ending 1905, a general increase is observed which, however, varies considerably on different roads, as shown in Fig. 57.

The cost of fuel per locomotive mile or per locomotive only serves as an illustration of expense on the various railroads and cannot be used for comparative purposes, since a variation in the price per ton, variation in the size of locomotives, change in operating or traffic conditions have such influence as to render it valueless as a basis of comparing performance.

For the purpose of illustrating this more thoroughly, the cost of fuel per tractive mile (average tractive force in pounds multiplied by total engine miles and divided by 1,000,000) is shown in the following table, and illustrated in Fig. 58, for the same railroads for the five years ending 1910.

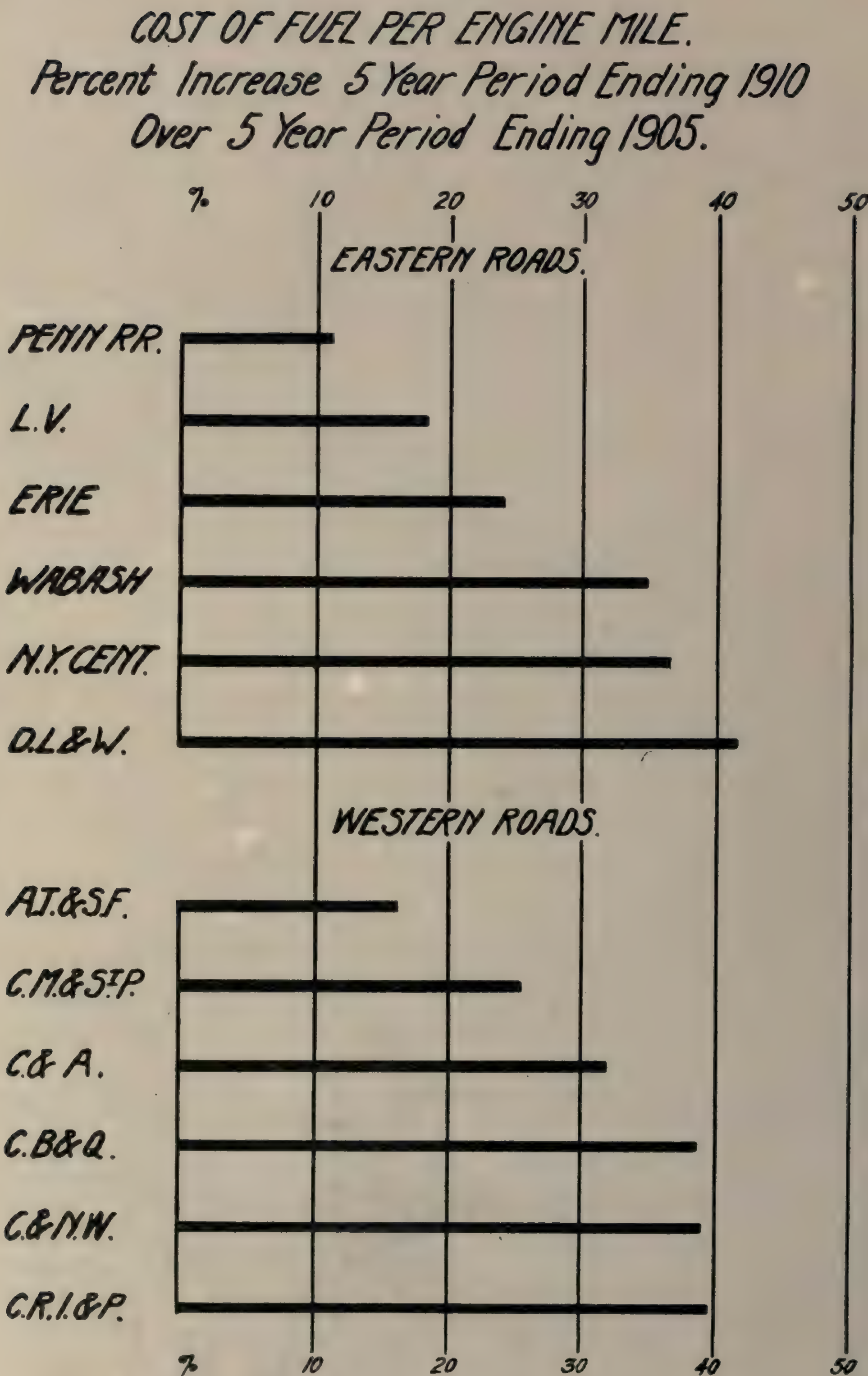

COST OF FUEL PER ENGINE MILE.
Percent Increase 5 Year Period Ending 1910
Over 5 Year Period Ending 1905.
%
10
20
30
40
50
EASTERN ROADS.
PENN RR.
L.V.
ERIE
WABASH
N.Y.CENT.
D.L.&W.
WESTERN ROADS.
A.T.&S.F.
C.M.&St.P.
C.& A.
C.B.&Q.
C.&N.W.
C.R.I.&P.
%
10
20
30
40
50

FIG. 57

The cost of locomotive fuel per tractive mile on the roads mentioned for the five-year period 1910, when compared with the cost in the previous four-year

Eastern Roads	Cost of Fuel Per Tractive Mile
Erie	$2.16
Penna. Railroad	3.23
N. Y. Central	3.75
D. L. & W.	3.76
Wabash	4.42
Lehigh Valley	5.10
Western Roads	
C. & A.	$3.37
C. B. & Q.	3.87
A. T. & S. F.	5.52
C. R. I & P.	5.74
C. & N. W.	6.01
C. M. & St. P.	6.32

period, does not show a general increase as on the locomotive mile basis. Fig. 59 and the accompanying table show this clearly.

Eastern Roads	Increase	Decrease
Penna. Railroad		10.0%
Lehigh Valley	1.6%	
Wabash	8.4	
N. Y. Central	10.0	
Erie	25.6	
D. L. & W.	31.5	
Western Roads		
A. T. & S. F.		10.4%
C. R. I. & P. (Avg. 3 yrs. ending 1905)		0.7
C. M. & St. P.	3.1%	
C. & A.	4.7	
C. B. & Q.	8.2	
C. & N. W.	10.3	

The Pennsylvania Railroad shows a marked decrease of 10 per cent. in the cost of locomotive fuel per tractive mile for the five-year period ending 1910, as compared with the previous four-year period, while the D., L. & W. shows an increase of 31.5 per cent. Of the western roads the Atchison decreased 10 per cent. and the C. & N. W. increased 10.3 per cent. during the same comparative periods.

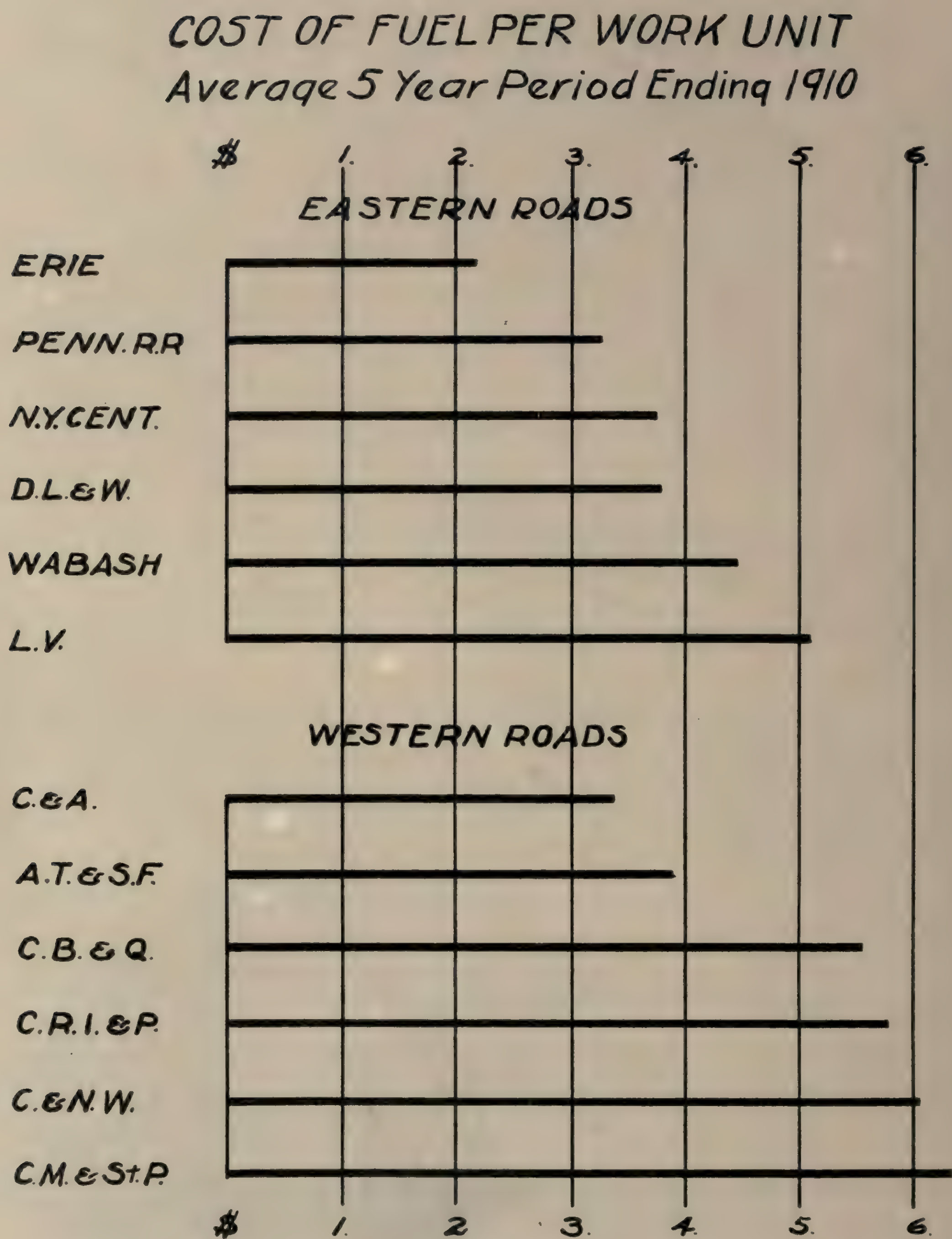

COST OF FUEL PER WORK UNIT
Average 5 Year Period Ending 1910
$
1.
2.
3.
4.
5.
6.
EASTERN ROADS
ERIE
PENN. R.R.
N.Y. CENT.
D.L.&W.
WABASH
L.V.
WESTERN ROADS
C.&A.
A.T.&S.F.
C.B.&Q.
C.R.I.&P.
C.&N.W.
C.M.&St.P.

Fig. 58

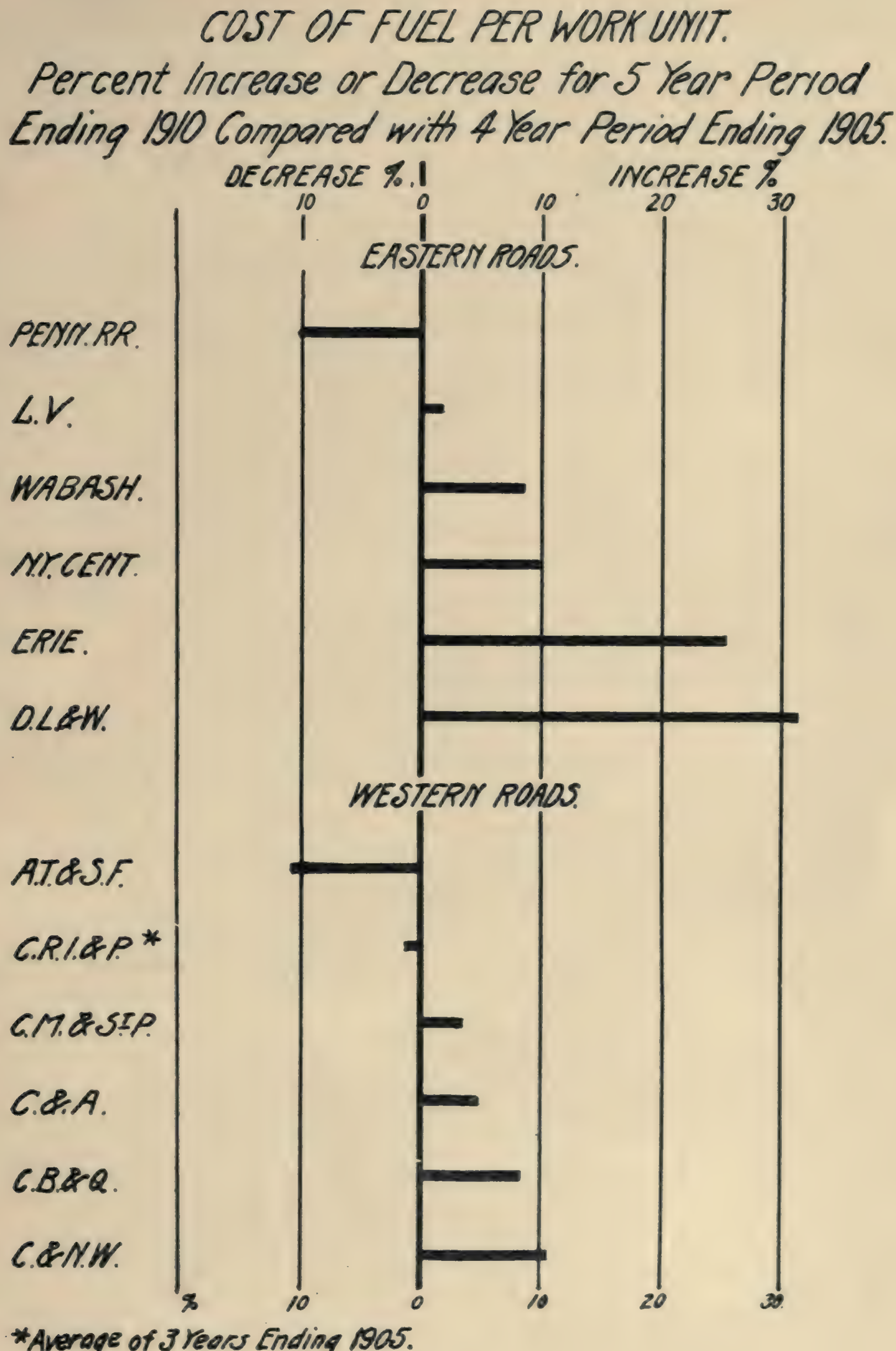

COST OF FUEL PER WORK UNIT.
Percent Increase or Decrease for 5 Year Period Ending 1910 Compared with 4 Year Period Ending 1905.
DECREASE %.
INCREASE %.
10
0
10
20
30
EASTERN ROADS.
PENN. RR.
L.V.
WABASH.
N.Y. CENT.
ERIE.
D.L.&W.
WESTERN ROADS.
A.T.&S.F.
C.R.I.&P. *
C.M.&St.P.
C.&A.
C.B.&Q.
C.&N.W.
%
10
0
10
20
30.
*Average of 3 Years Ending 1905.

Fig. 59

To further illustrate what erroneous conclusions may be drawn when the cost of fuel alone is used, the following statement is given of prices paid on various railroads per ton of fuel as shown on the Interstate Commerce Commission records for 1910.

Eastern Roads	Cost Per Ton
N. Y. N. H. & H.	$2.93
N. Y. Central	1.70
Lehigh Valley	1.60
D. L. & W.	1.43
Erie	1.37
Penna. Railroad	1.36
Southern Railway	1.16
L. & N.	1.12
Western Roads	
Northern Pacific	$2.76
Great Northern	2.56
C. M. & St. P.	2.24
C. & N. W.	1.99
C. R. I. & P.	1.98
Union Pacific	1.74
A. T. & S. F.	1.79

The cost of fuel for locomotives is largely dependent upon the geographical location of the railroad. Railroads having mileage within coal mining districts pay considerably less for the fuel than those located at a distance and, consequently, the comparisons cannot be on a cost basis.

An example of the extremes in locomotive fuel costs is furnished by the Northern Pacific and the B. & O. for the year 1910, as follows:

	Locomotive Miles	Cost of Fuel
Baltimore & Ohio	64,316,068	$5,406,759
Northern Pacific	35,810,364	7,690,841

In other words, the Northern Pacific, with 44.3 per cent. less locomotive miles, expended 42.3 per cent. more for fuel than the B. & O.

From the foregoing data it is evident that comparisons of fuel performance between different periods or railroads must be on the quantity consumed rather than on the cost.

As the tractive mile combines the size of the locomotives and the service rendered, the average quantity consumed on this basis is of considerable value.

The following table, with accompanying charts, Figs. 60 and 61 shows the tons of fuel per tractive mile on a number of representative railroads for the four years 1908, 1909, 1910 and 1911.

Tons of Fuel Per Tractive Mile.

	1908	1909	1910	1911
Penn R. R.	2.36 tons	2.23 tons	2.28 tons	2.28 tons
N. Y. Central	2.25	2.14	2.12	2.06
N. Y. N. H. & H.	2.59	2.50	2.59	2.59
Erie	3.12	3.09	2.92	2.87
B. & O.	2.60	2.62	2.62	2.64
D. & H.	2.76	3.08	2.91	2.89
D. L. & W.	2.98	2.91	3.04	3.07
Lehigh Val.	3.12	3.09	2.98	3.14
Phil. & Read.	2.94	2.87	2.90	3.00
C. R. R. of N. J.	2.82	2.87	2.84	2.88
Atl. Coast L.	2.41	2.34	2.49	2.58
C. & O.	2.43	2.38	2.37	2.54
N. & W.	2.57	2.79	2.88	2.89
Seab. Air L.	2.25	2.14	2.38	2.48
Southern	2.63	2.68	2.65	2.58
Lou. & Nash.	2.81	2.72	2.73	2.71
Mob. & Ohio.	2.65	2.84	2.83	3.03
Nash. C. & St. L.	2.31	2.63	2.29	2.48

Tons of Fuel Per Tractive Mile.

	1908	1909	1910	1911
Pere Marq.	3.14 tons	2.91 tons	2.85 tons	3.05 tons
Mich. Cent.	2.54	2.50	2.29	2.24
N. Y. C. & St. L.	3.35	3.26	3.34	3.32
C. H. & D.	3.57	3.50	3.32	3.57
C. C. C. & St. L.	2.61	2.54	2.56	2.51
Vandalia	3.01	2.96	2.98	3.11
Ill. Central	3.28	3.26	3.24	3.22
C. B. & Q.	3.10	3.21	3.28	3.00
C. & N. W.	3.26	3.35	3.36	3.29
C. R. I. & P.	2.78	2.84	2.79	2.82
Frisco	2.79	2.81	2.83	2.74
M. K. & T.	2.73	2.75	2.77	2.69
C. & A.	3.02	2.96	3.02	2.92
C. St. P. M. & O.	2.64	2.63	2.72	2.77
M. St. P. & S. S. M.	2.15	2.06	2.28	2.08
Union Pac.	3.10	3.15	3.17	3.24
Santa Fe Sys.	2.55	2.43	2.50	2.41
Nor. Pac.	2.77	2.72	2.65	2.69

While this is the best available unit, there are many factors which will modify the value of these comparisons, and no definite conclusions can be reached without a careful analysis of all influencing conditions.


TONS OF FUEL PER TRACTIVE MILE.
TONS. – 0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
PENNA. R.R.
N.Y. CENT.
N.Y.N.H.&H.
ERIE.
B.&O.
D.&H.
D.L.&W.
LEHIGH VAL.
PHILA.&READ.
C.R.R. OF N.J.
ATL. COAST LI.
C.&O.
N.&W.
SEAB. AIR LI.
SOUTHERN.
LOU.&NASH.
MOB.&OHIO.
NASH.C.&ST.L.
1908
1909
1910
1911

Fig. 60

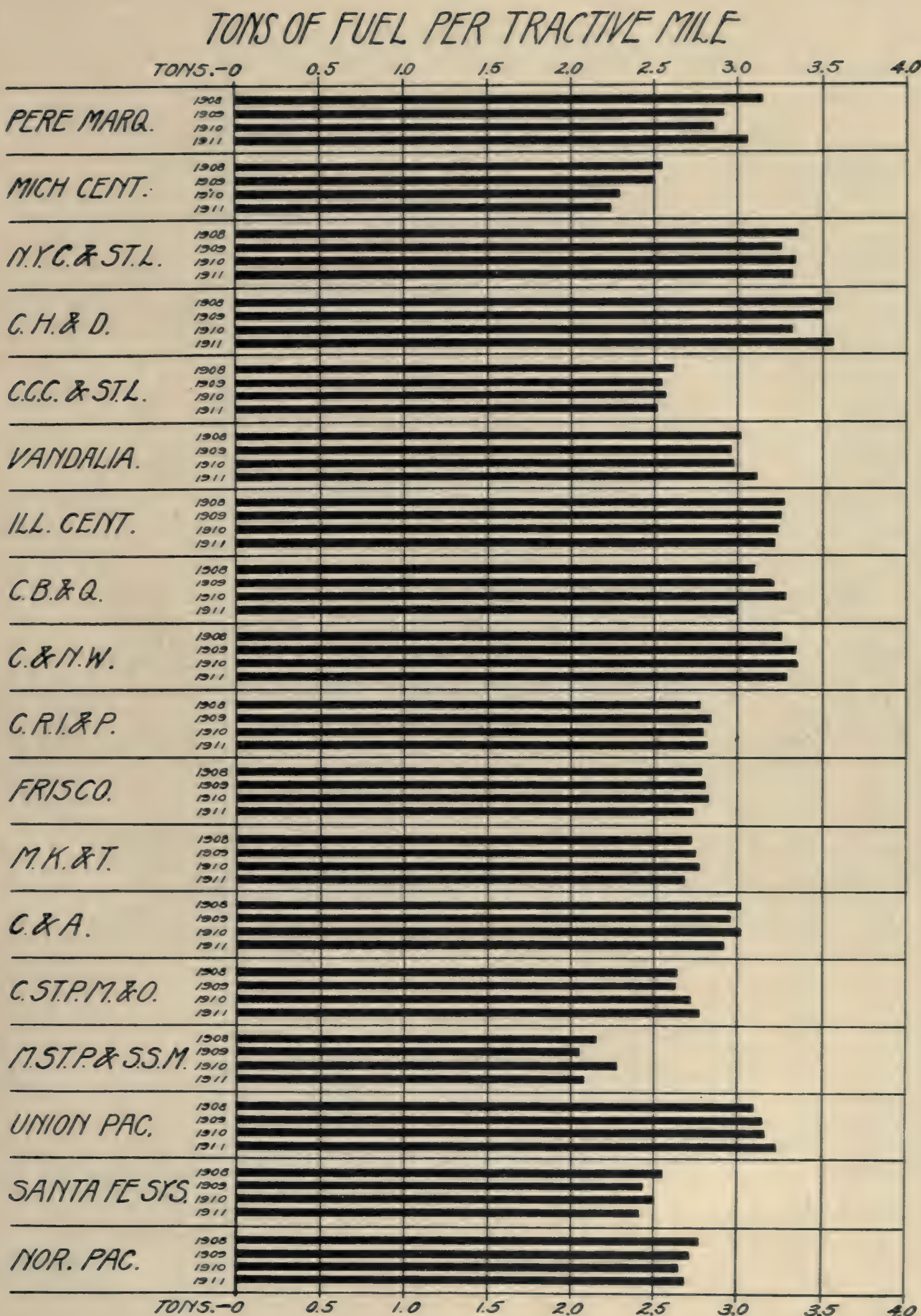

TONS OF FUEL PER TRACTIVE MILE
TONS.—0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0
PERE MARQ.
MICH CENT.
N.Y.C.& ST.L.
C.H.& D.
C.C.C.& ST.L.
VANDALIA.
ILL. CENT.
C.B.& Q.
C.& N.W.
C.R.I.& P.
FRISCO.
M.K.& T.
C.& A.
C.ST.P.M.& O.
M.ST.P.& S.S.M.
UNION PAC.
SANTA FE SYS.
NOR. PAC.
1908
1909
1910
1911
TONS.—0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0

FIG. 61

Locomotives of equal tractive force will burn more fuel per mile run on heavy grades in mountainous districts than those operating in level countries. The quality of fuel used will also influence the consumption as a greater quantity of low-grade fuel will be required than of first-class fuel in developing the same horse-power.

Railroads operating in the Eastern States having access to the best grade of bituminous coal, as the New York Central, Pennsylvania and Chesapeake & Ohio, should use less fuel than western railroads with similar grades using sub-bituminous and lignite coals. The average heat units per ton of the various grades of fuel would be of valuable assistance in comparing performance on fuel, but as this data is not available, this study cannot be made as extensive as is desirable.

While the fuel data furnished the Interstate Commerce Commission includes the fuel used by oil-burning locomotives reduced to a coal equivalent, it would permit of more satisfactory analysis, if separate records were maintained for oil and coal-burning locomotives.

Methods of operation (viz.: the tonnage and speed of trains), traffic conditions and physical characteristics, all have substantial influence on fuel consumption and no definite conclusions can be reached without full consideration being given these factors. Since the records of the Interstate Commerce Commission at present do not contain this information, this study has been made with such data as is available.

Railroads traversing the same general territory have, as a rule, the same operating conditions and have access to the same grade of fuel, so that comparisons among roads similarly situated possess considerable value on fuel consumption.

The C. & N. W. and the M. St. P. & S. S. M. occupy the same general territory, handle the same general traffic and should in a measure use the same grade of fuel. The percentage of total tractive force on these roads divided between compound and single expansion locomotives is as follows:

	Compound	Single Expansion
C. & N. W.	....	100%
M. St. P. & S. S. M.	38.4%	60.8

In order to compare the fuel consumption and locomotive maintenance for as long a period as possible, the figures have been taken for the years 1910 and 1911. As extensive additions were made to the mileage operated by the M. St. P. & S. S. M. in 1909, it is impractical to include more than the two years mentioned. The fuel consumption and locomotive repair costs per tractive mile for the two years, which are illustrated in Fig. 62, are as follows:

	Tons Fuel Per Tractive Mile	Loco. Repairs Per Tractive Mile
C. & N. W.	3.33	$2.82
M. St. P. & S. S. M.	2.17	3.10

From the above it is apparent that locomotive maintenance on the M. St. P. & S. S. M. was 10 per cent. greater and the fuel consumption was 35 per cent. less than on the C. & N. W.

Considerable variation is in evidence in the fuel performance of freight locomotives, on the basis of the revenue ton mileage for the same two years.

The tons of freight fuel per 10,000 revenue ton miles for this period on the two roads are as follows, Fig. 62:

C. & N. W. .... 4.22 tons
M. St. P. & S. S. M. .... 1.80 "

This shows a reduction of 57 per cent. in freight fuel consumption on this basis. As the revenue ton miles do not include the ton mileage of company material, this figure cannot be taken as final and, unfortunately, the Interstate Commerce Commission records do not contain this information. Neither do these records show the tractive force or total miles run by locomotives in freight service, so the study must of necessity be confined to the figures shown herewith.

If these records contained the number of compound and single expansion locomotives in freight and passenger service, the fuel consumption, miles run, tractive force, and maintenance costs of each class, a much more valuable analysis could be

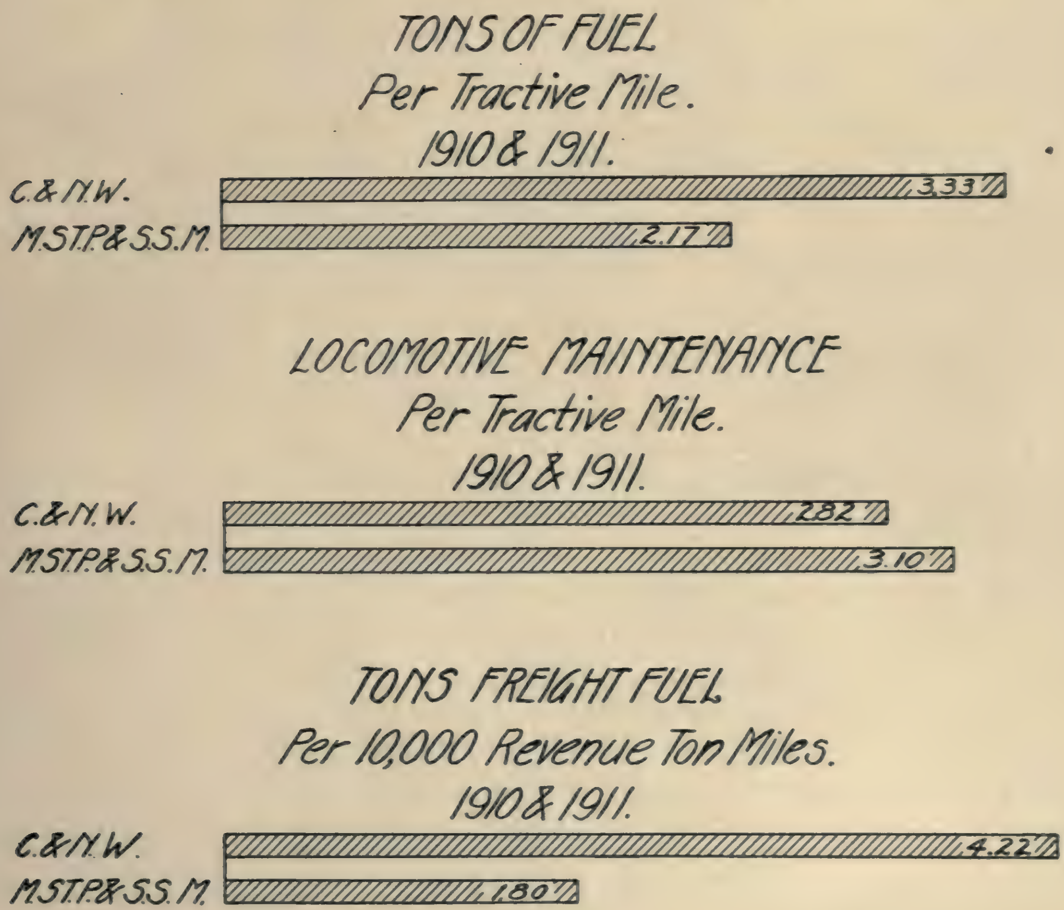


Fig. 62

made. As the maintenance of all locomotives on the basis of cost per tractive mile seems to indicate that compound locomotives are slightly more expensive to maintain, it is exceedingly unfortunate that the situation cannot be analyzed thoroughly.

The total maintenance costs of all locomotives on the Northwestern for the two years was $7,217,338, while the total cost of locomotive fuel for the same period was $16,412,054, or 227 per cent. that of locomotive maintenance.

If the locomotive maintenance cost per tractive mile on the Northwestern had been equal to that on the M. St. P. & S. S. M., the total expenditure per locomotive maintenance for the two years would have increased 9.9 per cent. or $715,000.

If the fuel consumption per 1,000 revenue ton miles on the Northwestern had been equal to that of the M. St. P. & S. S. M., there would have been a reduction for the two years in the fuel expense for freight service alone of $5,298,206.

Similarly, if the fuel performance per tractive mile for all classes of service on the Northwestern had been equal to that of the M. St. P. & S. S. M., the total expenditure for fuel during this period would have been reduced $5,850,000.

From the figures just quoted it is evident that an increase of $715,000 in locomotive maintenance costs on the Northwestern would have permitted a reduction of $5,850,000 in fuel costs, effecting a net saving of $5,135,000 in the two years.

This represents an annual saving of $2,567,500, and is equal to 4.8 per cent. of the total operating expenses and 8.3 per cent. of the cost of conducting transportation. Such a saving would reduce the operating ratio from 70.8 per cent. to 67.3 per cent., and reduce the transportation expense percentage of operating expenses (which is now considerably higher than any other trunk line) from 58.2 per cent. to 56.0 per cent.

An annual saving of $2,566,000 in freight fuel is equal to 5.2 per cent. in the freight earnings, and such a sum is sufficient to pay the regular 7 per cent. dividend on practically thirty-six million six hundred and fifty thousand ($36,650,000) dollars of common stock.

The two roads just studied are, however, under different managements and difference in methods of operation affect the total performance.

For example: Lighter tonnage per train and faster train schedules will materially affect the fuel consumption, indicating the necessity of a careful survey of the entire situation before a final decision is reached.

The Michigan Central and the C. C. C. & St. L. traversing the same general territory and handling similar traffic offer a better study than that just presented, since these roads being under the same management, methods of operation and maintenance should be more nearly identical and consequently permit of more satisfactory comparisons.

The percentage of locomotive tractive force in compound and single expansion locomotives on these two roads is as follows:

	Compound	Simple
C. C. C. & St. L.	.....	100%
Michigan Central	20.5%	79.5

The fuel consumption and locomotive maintenance costs on a tractive mile basis for the two years 1910 and 1911 are as follows:

	Tons Fuel Per Tractive Mile	Loco. Repairs Per Tractive Mile
C. C. C. & St. L.	2.53	$2.89
Michigan Central	2.26	2.43

Under similar methods of operation and maintenance the Michigan Central, with approximately 21 per cent. of total tractive force in compound locomotives, shows a reduction in total locomotive performance under the C. C. C. & St. L. of 10.7 per cent. in fuel and 16 per cent. in repair costs.

The fuel consumption in freight service, on the basis of the revenue ton mileage for the two roads for the same period is (Fig. 63):

	Tons Freight Fuel Per 10,000 R. T. M.
C. C. C. & St. L.	2.74
Michigan Central	2.35

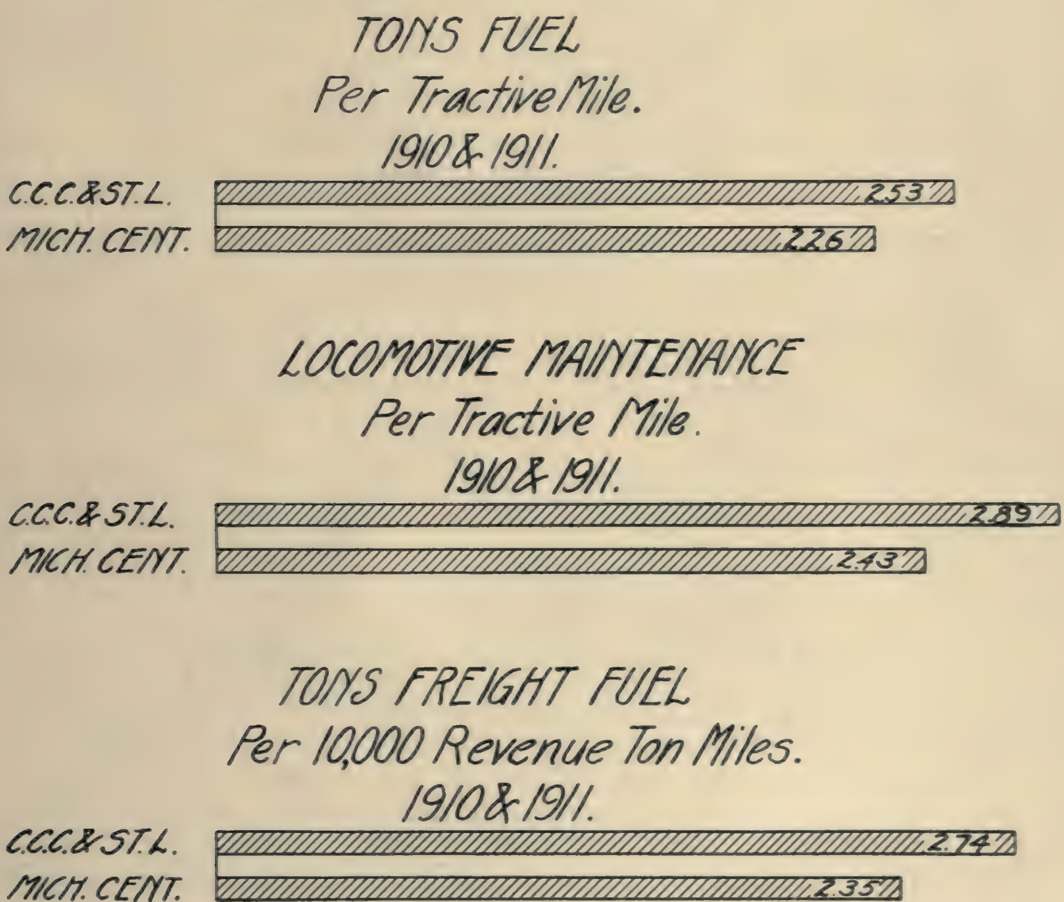


Fig. 63

This shows a reduction in freight fuel consumption of 14.2 per cent. in favor of the Michigan Central.

Since operating and maintenance methods on these two railroads should be fairly identical, the reduction of 16 per cent. in locomotive maintenance costs on the Michigan Central as compared with the C. C. C. & St. L. would have a tendency to dispute the assertion that compound locomotives cost more to maintain per unit of work, while the fuel economy is very evident. It is to be considered that final conclusions cannot be made since but 21 per cent. of the tractive force of the Michigan Central is in compound locomotives, though the figures are apparently sufficient to indicate that the maintenance of compound locomotives is not sufficiently high to prohibit their use as power units.

Further, as service conditions are similar on these two roads, valuable comparative data becomes available which will serve to confirm or controvert the statement that compound locomotives are out of service more than single expansion locomotives.

The following figures show the average miles run per freight locomotive and the average 1,000 revenue ton miles per freight locomotive for the two years 1910 and 1911 (Fig. 64):

	Miles Per Frt. Loco.	1000 R. T. M. Miles Per Frt. Loco.
C. C. C. & St. L.	20,887	8,340
Michigan Central	26,849	9,836

The performance in both items is extremely favorable to the Michigan Central, since the average miles run per freight locomotive is 28.5 per cent. greater and the 1,000 revenue ton miles per freight locomotive is 18 per cent. greater than on the C. C. C. & St. L.

The average mileage of all locomotives on the two roads for the two years is as follows (Fig. 64):

	Average Mileage Per Total Locomotive
C. C. C. & St. L.	30,698
Michigan Central	34,283

The average mileage per total locomotive is valuable since the total locomotive miles includes all mileage in both revenue and non-revenue service, while the mileage of freight locomotives is that of revenue service only.

These figures also are more favorable for the Michigan Central, since the average miles run by all locomotives in the two years is 11.8 per cent. greater than on the C. C. C. & St. L. If there were separate data covering maintenance, miles run, tonnage handled, fuel consumption, etc., for the two classes of power units the study could be made more conclusive.

The conclusions drawn from the performance on the two roads just studied are, however, apparently sufficient to controvert the generally accepted opinions that compound locomotives are more expensive to maintain and the time out of service is more extensive than in the case of single expansion locomotives.

It further indicates that compound locomotives are active agents in promoting fuel economy, and while the management of the Michigan Central is to be compli-

mented on the use of this type of power units, it is evident that the consumption of fuel could be further reduced by having all of their power of compound design rather than the 20.5 per cent. shown above.

It is also interesting to compare the performance on the Michigan Central with other railroads operating in the same general territory, having all of their power in single expansion locomotives for the year 1911 as follows:

	Tons Fuel Per Tractive Mile	Loco. Repairs Per Tractive Mile
C. H. & D.	3.57	$4.03
P. C. C. & St. L.	2.60	3.09
Ill. Central	3.22	4.17
Vandalia	3.11	3.37
Mich. Central	2.24	2.47

Another study of similar nature of railroads operating in the southern states affords us further information. The N. C. & St. L. has approximately 6 per cent.

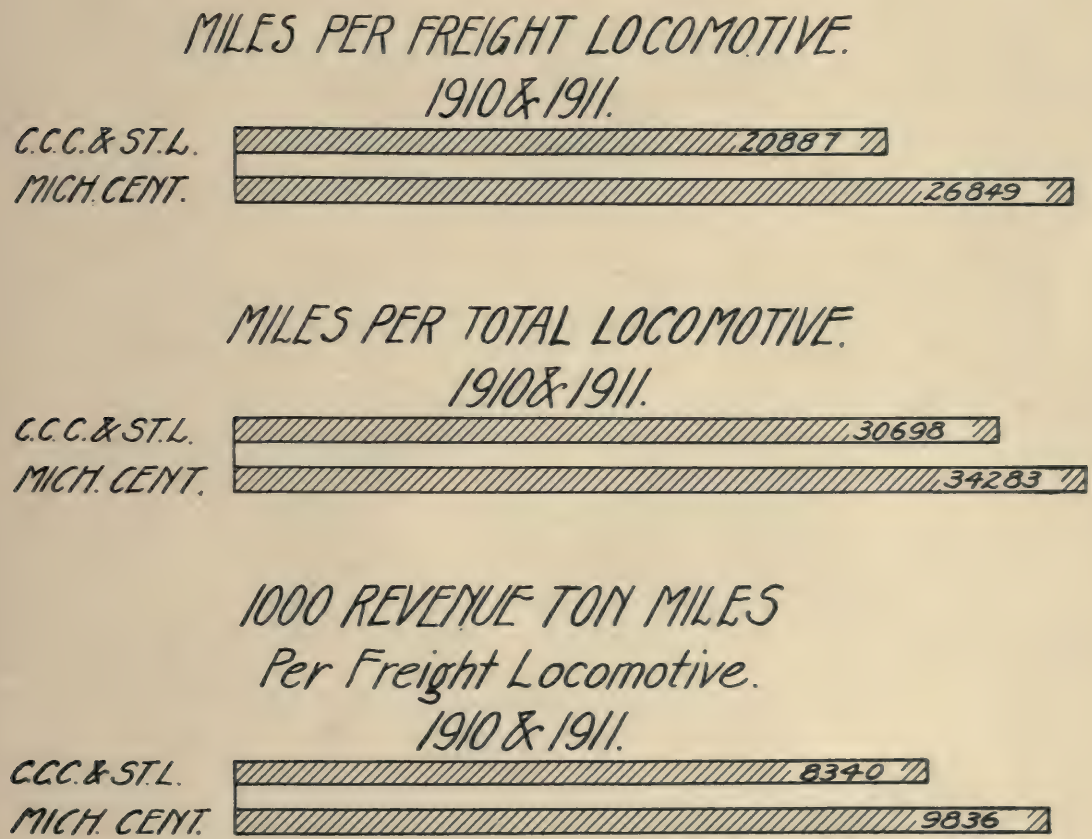


Fig. 64

of the total tractive force in compound locomotives, while the L. & N. and the M. & O. have no power units other than single expansion locomotives.

The performance on these roads for the year 1911 was:

	Tons Fuel Per Tractive Mile	Loco. Repairs Per Tractive Mile
N. C. & St. L.	2.48	$2.72
L. & N.	2.71	3.02
M. & O.	3.03	2.94

As has been previously mentioned, it is impractical to make deductions from the performances just mentioned, due to the small percentage of compound locomotives and the other factors affecting fuel consumption.

The New York Central, for example, has approximately 5 per cent. of the total tractive force in compound locomotives, though it is not improbable that the use of superheaters has been an important factor in obtaining an average of 2.06 tons of fuel per tractive mile in 1911. This performance is the lowest of any of the railroads shown in Figs. 60 and 61 and considerably lower than other railroads similarly situated.

Unfortunately the railroads are not required to make a report of locomotives equipped with superheaters, and in the absence of such information it is impossible to determine the influence of their use upon the fuel records illustrated in Figs. 60 and 61, and this analysis must be left until such information becomes available.

Tests of superheaters on various railroads seem to indicate the fuel economy through their use on single expansion locomotives is almost equal to that secured through the use of compound locomotives, as compared with those of single expansion. Since the use of superheated steam, in place of saturated, is productive of substantial economy in single expansion locomotives, it would appear that similar additional fuel economy is possible through its use on compound locomotives.

As previously stated, an analysis of fuel performance on any railroad must necessarily consider the physical characteristics, operating conditions, especially as regards speed, volume and character of traffic, variation in quality of fuel and all influencing and contingent factors.

In order to permit a more extensive study provision should be made for the various railroads to furnish additional information. This should include the heat value of the fuel, the maintenance, mileage and fuel consumption of compound and single expansion locomotives, separately reported. The necessary information should also be on file to permit a thorough analysis of the influence of superheaters on the fuel consumption and operating cost.

Notwithstanding the lack of details in the performance of the various roads, it is apparent from the studies herewith presented that the fuel consumption per tractive mile is extremely favorable to compound locomotives, without increase in maintenance sufficient to prohibit their use.

The average fuel consumption on all the railroads in the United States during the year 1911 was 2.63 tons per tractive mile. Compared with this is the performance of the M. St. P. & S. S. M. with 39 per cent. compound locomotives and 2.08 tons per tractive mile, the Michigan Central with 21 per cent. compounds and

2.24 tons and the N. C. & St. L. with 6 per cent. compounds and 2.48 tons, all of which tends to indicate that if all of the locomotives were of the compound type an average performance of 1.60 tons per tractive mile should have been attained.

Such a performance would mean a saving of one hundred million dollars ($100,000,000) per year.

With such data available as has been presented herewith, the question arises as to why railroad managers have not paid more attention to the matter of compound locomotives, and in this connection it may be well to enumerate some of the reasons therefore.

The first, as has been pointed out throughout this treatise, is the absence in the past of adequate comparative units of operating costs and performance. The continuance of this condition has resulted in erroneous conclusions and caused false standards to be built up in railroad operation, and these studies serve to further emphasize the necessity of a decided improvement in existing methods.

Second, the manner in which the compound locomotives were first introduced on American railways.

The rational course to pursue in the development of any mechanical device is to first build a small number for experimental purposes, subject them to thorough tests under all probable operating conditions, locate the imperfections and then make the necessary corrections.

Such, however, is not the history of the compound locomotives on American railways. Foreign railroads have long used compound locomotives and have made a success of this principle—due in a large measure to excellence of design, developed by persistent efforts to locate and remedy all defects. American builders would have done well to have used these principles, but not so—their early efforts to apply the compound principle resulted in design without mechanical refinement. While such a condition was to be expected in so radical departure as the change from the single expansion to the compound type, apparently no effort was made to detect and eliminate the imperfections.

As the result of the persistent efforts of accomplished locomotive salesmen, many railroad operating officials were persuaded to place in service large numbers of the compound locomotives of abortive design, leaving the responsibility and expense of the development and improvement to be borne by the railroads.

This resulted in high maintenance costs, excessive time out of service and extensive delays to transportation. This latter feature was so noticeable as to attract the attention of those officials who direct the handling of trains and prejudiced their opinion as to the value of compound locomotives as power units.

Many railroad officials found it advisable to convert their compound locomotives back to the single expansion type. This not only resulted in an enormous expense, but flooded the already overcrowded repair shops with unnecessary work and was so extensive as to excite unfavorable comment among the employes, from whose ranks supervising officers were later secured and resulted in an everlasting prejudice against the compound locomotive.

It is therefore no surprise that the costly experiments with the early designs of compound locomotives served to prejudice railroad officials against their use and

place a stigma upon any locomotive in which the compounding principle was incorporated which will be difficult to remove.

Another probable reason is due to the somewhat peculiar division of responsibilities in railroad organization—the mechanical department is responsible for the cost of locomotive maintenance, while the transportation department is responsible for the cost of locomotive fuel. Certain units with respect to fuel consumption and locomotive repairs having been established, even though on an erroneous basis, are adhered to and variations in departmental expenses are very closely watched.

Mechanical department officials being held to account for the maintenance costs, without due regard being given to performance, would naturally hesitate to recommend any change in motive power design if there is any possibility of increased expense in their department. It is possible therefore that mechanical officials have hesitated in incurring the criticism of their superior officers, and have preferred to continue the use of single expansion locomotives to avoid increasing expenses for which they would be held directly responsible.

A further reason may be ultra-conservatism of the railroad officials, which has become evident from time to time, and particularly when any changes in the existing order of things are proposed.

In the *Railway Age Gazette,* under date of November 24, 1911, Mr. I. C. Fritch, Chief Engineer, Chicago Great Western, pointed out that considerable economy might be effected in the use of fuel, from which article the following extracts are taken:

> "The very nature of the transportation industry, by virtue of its operations being scattered over extensive area, affords formidable opportunity of waste and extravagance, which in other branches of industrial activity may be more fully controlled and regulated because of the possibility of supervising more closely their various operations, and thereby reducing waste and extravagance to a minimum.
>
> "True economy does not mean niggardness, but it does mean the best for the purpose designed; the best brains in the employe, the best tools in the shop, the best equipment and roadways on railroads, and above all, an organization which possess all of these in proper proportion and commensurate with its needs.
>
> "The losses incurred in the use of fuel on railways may be classified in two parts: First, those due to the limitations imposed upon the locomotive boiler plant, causing thereby certain defects resulting in incomplete combustion and lack of full utilization of the total heat units in the fuel. Many of the defects or deficiencies may be overcome, and some of them are in gradual process of elimination or improvement.
>
> "Second, the losses due to carelessness or inefficiency of the human element in firing fuel on locomotives. Much of this loss, if not all, may be eliminated by this process of education of firemen in proper methods of firing and co-operation on the part of the engineer in so working the locomotive that fuel will be fired at the proper time and the fuel utilization of heat units effected in the evaporation of water and the generation of steam.

> "While, of course, 100 per cent. efficiency in this expenditure is not and never will be a possibility, there is reason to assume from the foregoing analysis that from 20 per cent. to 25 per cent. of the losses now incurred may be eliminated, effecting a saving of from \$40,000,000 to \$50,000,000 per annum."

Since the above letter was published various articles have appeared in which railroad officials have endeavored to controvert Mr. Fritch's statement that an annual saving of \$50,000,000 is possible in the fuel expenses.

One of particular note by J. F. Sugrue, Assistant Superintendent, Houston & Texas Central R. R., appeared in the *Railway Age Gazette* of February 16, 1912, from which the following self-explanatory quotations are taken:

> "Economy has been carried to such an extreme on railways that it is positively dangerous to economize further.
>
> "Other theorists point to heavy losses in fuel consumption, and we all know that there are losses. The subject has had more study, perhaps, from the economy standpoint than any other. Every method known to theory or practice has been tried, even to reburning the smoke, and after all nothing better has been found than an intelligent fireman, who takes advantage of the particular conditions met with in different trains, engines, coals, grades and weather, that he may find necessary to know in order to get the best results. This knowledge he must gain by actual experience and practice.
>
> "Practically all roads are using or have tried every means known to science, theory and practice to reduce their fuel expense. and there are few who have not in their service the best informed men that can be found, whose sole duty it is to reduce fuel consumption. In the article by Mr. Fritch results of a very satisfactory fuel test are shown. but it does not follow that the same results could be obtained in ordinary practice, nor that there was a real saving in dollars and cents in the actual test.
>
> "Railways practice every economy that they have been able to devise that will save money. The practice of economy at any cost is an entirely different matter."

These statements from a man occupying a high position in railroad circles is of particular note, in conjunction with the data in the foregoing pages with reference to the compound locomotives. They are of especial interest when it is considered that the motive power on the railroad he represents consists entirely of single expansion locomotives with an average fuel consumption for 1911 of 3.08 tons per tractive mile.

It is also worthy of mention that the annual expenditure for fuel on the Houston & Texas Central constitutes 16.2 per cent. of the total operating expenses and absorbs 12.1 per cent. of the total gross earnings. while locomotive maintenance for 1911 was 5.5 per cent. of the operating expenses and equivalent to 4.1 per cent. of the gross earnings. If the fuel consumption was reduced to 2 tons per tractive mile the reduction in fuel costs would be greater than the total expenditure for locomotive maintenance during the year 1911.

As previously stated, it is probable this ultra-conservatism on the part of the majority of railroad operating officials, coupled with the absence of proper com-

parative standards, has prevented the more extensive use of compound locomotives with their attendant saving in fuel consumption.

While compounding and superheating are advantageous in securing results, they are by no means the only sources through which economy may be secured. To show further possibilities in this respect the following extracts are taken from a paper on "Locomotive Drafting and Its Relation to Fuel Consumption," presented at the annual meeting of the International Railway Fuel Association.

> "The method of drafting a locomotive has varied but very little since the introduction of the multi-tubular locomotive boiler by Segium in 1829.
>
> "The art of making an engine a good steamer, if it may be properly termed an art, consists largely in haphazard, cut-and-try methods.
>
> "The simplest and most effective way to increase the draft and produce a good steaming engine is to reduce the size of the exhaust nozzle. Although this method of securing increased draft is easily understood by men directly charged with getting the locomotive in operating condition, yet few realize the tremendous tax such an arrangement has upon the effective power of the engine.
>
> "Drafting a locomotive is accomplished at the loss of considerable energy. The source of power is the exhaust steam from the cylinders and the useful work accomplished is represented by the volume of furnace gases which are delivered against the differences in pressure existing between the atmosphere and the smoke-box. In order that the power of the jet may be sufficient, it is necessary that the engine of a locomotive should exhaust against a back pressure. The presence of the back pressure tends to decrease the cylinder performance and thus decrease the available power of the locomotive.
>
> "The actual horsepower utilized producing a draft in any given class of locomotive is taken as the horsepower, due to the back pressure in the cylinders. This back pressure horsepower is not entirely chargeable to the production of draft because of the impossibility of operating non-condensing engines without at least three or four pounds of back pressure, though a greater part of the power thus expended is used in producing draft alone.
>
> "As this back pressure is acting against the piston, it can be computed as actual horsepower developed but not utilized. When computed in this manner this horsepower is found to amount to from 10 per cent. of the total available power of the engine at low speeds to over 50 per cent. of the total available power at high speeds.
>
> "This condition holds true with both ordinary freight and passenger engines, but for Mallet engines the losses are much greater.
>
> "If other means could be provided to draw the necessary volume of gases through the boiler for the same rate of combustion possible with a steam jet, at an expenditure of power somewhere near the calculated power to draw the gases through the boiler, a tremendous saving in power would be accomplished. The power thus saved could be utilized in useful work, either as increased speed or as a direct saving in fuel consumption."

From the data submitted, the available power above requirements to produce the necessary draft in single expansion locomotives averages 58 per cent. of the

dynamometer horsepower developed at a speed of 60 miles per hour. In compound passenger locomotives at the same speed this available horsepower above the requirements was 107 per cent. of the dynamometer horsepower.

In single expansion freight locomotives, the additional horsepower available at a speed of 25 miles per hour is 20 per cent. of the power developed, and at the same speed in the compound freight locomotive the additional horsepower is 35 per cent. of the power developed.

In the Mallet compound locomotive, at a speed of 25 miles per hour, the additional power available amounts to 85 per cent. of the total developed, indicating that the percentage would be much higher at faster speeds.

Since any increase in the dynamometer horsepower of a locomotive is a net gain, the possibilities of improving the efficiency of locomotives is very apparent. As many locomotives cannot start a larger train than now handled, the increase in horsepower at regular speed would result in the present power being developed with less fuel consumption.

This possible saving in fuel consumption reduced to percentages is as follows:

Single expansion passenger locomotives........	36%
Single expansion freight locomotives...........	17
Compound passenger locomotives..............	52
Compound freight locomotives.................	26
Mallet compound freight locomotives..........	46

These figures indicate very clearly the percentage of power wasted and the attendant loss of fuel due to the use of the exhaust in the production of draft.

The designers of stationary power plants have, during the past few years, developed mechanical drafting through the use of fans which permits the intensity of the draft to vary according to the requirements of the furnace. The published data covering the performance of this apparatus are such as to appear that similar devices could be made applicable for locomotive service and the possible economies are sufficient to warrant extensive experiment.

In the foregoing tabulation showing the saving in fuel consumption which can be effected through the elimination of back pressure in the cylinders of a locomotive, particular attention is directed to the possibilities of greater increase in power in compounds over those of the single expansion type.

Since the fuel economy of compound locomotives of the present design as compared with single expansion locomotives has been demonstrated, it is evident that the value of compounds will be further augmented by the proposed change in design.

As indicated previously in this study, a saving of $100,000,000 in the annual expenditure for fuel is possible by the substitution of compounds in place of single expansion locomotives. It follows that our estimate will have to be substantially increased.

The value of Mallet type locomotives in reducing maintenance, fuel and other operating costs per ton mile has been clearly established, both in helper and road service, though they have been generally regarded as being only suitable for low-

speed service. Since it has been demonstrated that the back pressure and not machine friction prevents the use of Mallets in fast service, the necessity of overcoming the difficulty is evident.

The steadily increasing tonnage to be handled and the necessity of reduction in the cost of operation has resulted in a substantial increase in the weight of trains and a consequent increase in the size of the locomotive. The Mallet type represents the latest development and all indications point to this design, replacing all others in freight service.

Similar conditions to those which have made the Mallet locomotive necessary in freight service are rapidly becoming evident in passenger service, as the latest design of passenger locomotive has nearly reached the limitations of size for a single unit. This is particularly in evidence in the number of fast passenger trains that now require two locomotives to enable a slight delay in the regular schedule to be overcome before reaching the terminal.

The logical conclusion is the adaptation of the Mallet type of locomotive for passenger service, as the weight of trains is steadily increasing and faster schedules are necessary to meet the demands of the service.

The power now developed by a Mallet locomotive at 25 miles per hour could be secured with 46 per cent. less fuel consumption by proper drafting and this saving would be proportionately greater at higher speeds. Through the alterations which are necessary in the drafting of a locomotive, the power now wasted in the back pressure can be converted into useful work and the Mallet type locomotive will be available for both freight and passenger service with substantial reduction in the cost of transportation, particularly in fuel.

It would therefore seem, after careful consideration, the way is pointed where an additional $50,000,000 saving can be effected in the annual expenditure for locomotive fuel. The estimate of Mr. Fritch of a possible fuel economy of $40,000,000 to $50,000,000, appears to be far too low as the possible figure is approximately three times that amount.

An annual saving of $150,000,000 is equivalent to a 5 per cent. profit on an investment of three billions of dollars ($3,000,000,000), a sum equal to more than the total capitalization of the New York Central, Pennsylvania, the Southern Pacific and their subsidiary companies.

The cost covering the application of such apparatus as is necessary to produce the required draft and prevent this present loss in fuel consumption is not available. Its application to existing locomotives would probably require considerable expense.

In the building of new locomotives the expenditure involved would be comparatively slight and as the number of new locomotives built annually is about 15 per cent. of the total in service it is evident that the major portion of the possible economy could be secured in a relatively short time.

The writer holds no brief in the interests of compound locomotives, nor in any of the various fuel-saving devices. Neither does he wish to appear as an advocate of any particular policy of railroad operation.

This research has been made, not as an accountant in verifying the accuracy of recorded data, but in the broader sense of accounting as an auditor, who reviews and analyzes a condition as reflected by the figures submitted.

No one individual can conceive, direct and execute unaided the task suggested in the foregoing pages. To conduct such a work to a successful conclusion will require the united efforts of all railroad officials whose duties in any manner affect the sum total.

This study is a plea to the operating officials of American railways, that a closer and more unprejudiced research should be given to the relative advantages of any type of locomotives or any devices which have demonstrated the results of actual economies in their performance.

When one considers the possible saving and that the fuel supply of the country is unrenewable and that the cost of fuel per unit must increase rather than decrease, it seems proper to urge that every effort be made to cause the unit of coal to produce a larger unit of performance.

The day has passed when haphazard methods should be tolerated in any business. Each department of every industry must be operated at the highest efficiency and tradition must give way to the logic of proven results.

NOTE.—Since this article has been written it is gratifying to note in the report of the performance of the test locomotive, 50,000, built by the American Locomotive Co., for experimental purposes the following comments:

> "It saves 28 per cent. in fuel as compared with another Pacific type locomotive of equal weight and conventional design.
>
> "Compared with a Pacific type equipped with the same fuel-saving devices, though not developed to the same degree of efficiency, it shows 13 per cent. average economy in fuel.
>
> "These are records from more than one test on different roads."

It is also interesting to read in the *Railway Age Gazette* of April 5, 1912, under the title of "Mallet Results in Road Service," referring to the performance of locomotives of this type on the Chesapeake & Ohio, as compared with the single expansion locomotives as follows:

> "Because of the fuel economy obtained with the superheater and brick arch in combination with compound cylinders, the Mallets save 43 per cent. in coal per ton mile as compared with the consolidations. This means that a Mallet will burn no more coal than a consolidation in doing 75 per cent. more work; in other words, the fireman's work on the Mallet is no harder and on the average is probably lighter than formerly on the consolidation. In addition to these important results, 70 per cent. more traffic could be handled with the existing track facilities in case of necessity if Mallets are used without exceeding the number of consolidation locomotives formerly required.
>
> "The reduction of over 5 cents per 1,000 ton-miles in the cost of operation becomes impressive when it is considered that on the basis of the present yearly traffic of the Hinton division alone this means a net saving, all factors considered, equal to the interest on $1,500,000 of 5 per cent. bonds.

"The accompanying itemized comparisons of the cost of operation of the two classes of locomotive deserves careful analysis. It is prepared from actual records, permitting of fair and just comparison and covers a period of 8 months, beginning with the installation of the second order of 24 Mallets, and includes all items of cost of operation except classified repairs. The item "maintenance" in each case includes only running repairs, as none of the Mallets have as yet received general repairs. Records from other roads, however, which have had the American Locomotive Company's Mallet in service for a sufficient length of time to determine the cost of classified repairs, as compared with the locomotives which they have replaced, show that while the cost per locomotive is higher the cost per ton mile is less."

Cost per 1,000 Ton-Miles of Mallets and Consolidations in Road Service.

	Cost Per 1000 Ton-Miles	
	Mallet	Consolidation
Fuel	$0.0285	$0.05
Wages, engine crew	.034	.047
Wages, train crew	.031	.054
Maintenance (running repairs only)	.0001	.0009
Enginehouse expense	.0002	.00015
Supplies	.00009	.00006
Total	$0.095	$0.152
Decrease due to use of Mallets	.057	

"From this experience, Mr. Walsh says, 'From every point of view we consider the Mallet engines a success.'"

It would appear in view of the statement of 43 per cent. saving in fuel per ton-mile as compared with the single consolidations that the arguments set forth in the preceding pages of this chapter are in a fair way to be substantiated.